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NINETIETH SESSION.

Monday, 16*th December* 1872.

SIR ALEXANDER GRANT, Bart., Vice-President, in the Chair.

The following Communications were read :—

1. On the Philological Genius and Character of the Neo-Hellenic Dialect. By Professor Blackie.

The Author showed by a historical review of the fortunes of Greece, through the Middle Ages, and under the successive influences of Turkish conquest and Turkish oppression, how the Greek language had escaped corruption to the degree that would have caused the birth of a new language in the way that Italian and the other Roman languages grew out of Latin. He then analysed the modern language, as it existed in current popular literature before the time of Coraes, that is, from the time of Theodore Ptochoprodromus to nearly the end of the last century, and showed that the losses and curtailments which it had unquestionably suffered in the course of so many centuries, were not such as materially to impair the strength and beauty of the language, which in its present state was partly to be regarded as a living bridge betwixt the present and the past, and as an altogether unique phenomenon in the history of human speech.

2. Laboratory Notes. By Professor Tait. Communicated, in his absence, by Professor G. Forbes.

1. On the Relation between Thermal, and Electric, Conductivity.

Reference was made to a previous paper by the author (Proceedings, 1867–8, p. 309), in which an attempt was made to apply to this subject the Theory of Dissipation of Energy.

Some years ago, a bar of German silver was procured, at the expense of the British Association, for the purpose of ascertaining whether its thermal, like its electric, conductivity is little altered by change of temperature. With this, Forbes' experiments have been carried out carefully through very great ranges of temperatures.

The exceedingly laborious calculations necessary to a complete determination are not yet carried out; but, by a rough graphic method, it has been ascertained that the alteration of conductivity, by rise of temperature, is at least very small compared with that observed in iron under the same circumstances.

2. On Electric Conductivity at a Red Heat.

This was a mere preliminary notice of what promises to be at once an interesting and an extended inquiry, to which I have been led by some recent results in thermo-electricity. At present, it may be stated that at, and above, a red heat the electric conductivity of iron seems to fall off much faster with increasing temperature than that of platinum. To such an extent does this take place, that I have endeavoured (as yet, however, unsuccessfully) to form a circuit in which the main resistance is an iron wire, and to obtain a *maximum* current by gradually shortening the wire. The fall in conducting power seems so very marked that some of it will remain, even I believe when allowance is made for the oxidation of the iron. I have ordered a special apparatus for the purpose of avoiding this source of uncertainty.

3. On the Thermo-Electric Relations of Pure Iron.

By the kindness of Dr Russell, of Bartholomew's Hospital, I have been enabled to experiment upon a ribbon of pure iron prepared by the late Dr Matthiessen. I reserve details until I can obtain the history and mode of preparation of the specimen examined, but I may state now that, when formed into thermo-electric circuits with various alloys of Platinum and Iridium (Proceedings, 1871–2, p. 773) it gives results, as to the position of neutral points, not differing more from those given under the same circumstances by various iron wires of commerce, than the latter do among themselves. Thus it appears that, in the thermo-electric diagram, the line even for pure iron is sinuous; and that the specific heat of electricity in it changes sign somewhere about a low red heat.

3. Note on the Rate of Decrease of Electric Conductivity with Increase of Temperature. By D. H. Marshall, M.A., Assistant to the Professor of Natural Philosophy. Communicated by Professor Tait.

These experiments were undertaken in order to determine how closely the hypothesis "that the electric resistance in a pure metal is directly as its absolute temperature" holds for various metals at two easily ascertained temperatures,—that of the air in the room, and the boiling point of water. The apparatus used was a Wheatstone's bridge; one coil of wire kept in a vessel of water at the temperature of the air in the room being put against another, which could be heated up to 100° C. The experiments showed that the rate of increase of resistance with temperature was different for hard and soft specimens of the same metal, being always less in the hard. This was further proved by additional experiments, which showed that sudden cooling always diminished the rate of increase of resistance, whereas if the metal were allowed to cool slowly after being boiled, the rate of increase of resistance was always sensibly increased.

The first two columns of figures give the ratio of the resistances at the two temperatures; the first and third give the ratios of the temperatures themselves in absolute scale; the fourth is the difference between the second and third, which will therefore show the amount and direction of deviation from the above hypothesis. When the number in the fourth column is +, the rate of increase of resistance with temperature is less than it would be according to the hypothesis; when −, greater.

Soft Crown Cu.	374	280	284·4	− 4·4
„	„	283	284·1	− 1·1
„	„	281	283·6	− 2·6
Soft C. Cu.	374	288·6	287	+ 1·6
„	„	285·6	285	+ ·6
„	„	286·7	285·8	+ ·9
Hard C. Cu.	374	319	288·1	+ 30·9
„	„	321	288·5	+ 32·5
„	„	319·6	288	+ 31·6
Soft Pt.	374	303·9	288·8	+ 15·1
„	„	303·9	289·2	+ 14·7
Hard Pt.	374	356	288·2	+ 67·8
Cd.	374	291·5	295·7	− 4·2
„	„	285	292·9	− 7·9
„	„	286·2	293·3	− 7·1
Au.	374	301·7	292·7	+ 9·0
„	„	304	292·2	+ 11·8
„	„	302·4	293·1	+ 9·3
Ag.	374	302·3	291·5	+ 10·8
„	„	303·1	291·8	+ 11·3
„	„	304·7	292·9	+ 11·8
Zn.	374	294·1	294·1	0·0
„	„	290·3	294·2	− 3·9
„	„	288·6	293·6	− 5·0
Fe.	374	283·8	292·8	− 9·0

Monday, 6th January 1873.

DAVID MILNE HOME, LL.D., Vice-President, in the Chair.

The Chairman said:—Before the papers in our to-night's programme of business are taken up there is a statement which, at the special request of the Council of this Society, I have to make from the chair. I have been requested to allude to the deaths of three much esteemed Fellows of this Society, which have occurred since our last ordinary meeting—Professor Macquorn Rankine of Glasgow University; the Very Rev. Dean Ramsay, Edinburgh; and Archibald Smith of Jordanhill. The Council think that it is only a fitting tribute to the memory of our deceased colleagues that I should express regret at the loss which we, in common with others, have sustained, and that I should also briefly allude to their connection with this Society and with science, leaving to a future occasion the duty of giving a fuller biographical account of each. Professor Rankine, when he died, was one of our vice-presidents, having joined the Society in the year 1850. Important scientific investigations were carried on by him, and were the subjects of numerous papers read at our meetings, and published in our Transactions. A series of six papers "On the Mechanical Action of Heat" gained for him our Keith prize in the year 1853. Our Transactions also contain papers by him "On the Centrifugal Theory of Electricity," "On the Specific Heat of Water at various Temperatures," "On the Absolute Zero of the Gas Thermometer," and "On the Thermal Efficacy of Molecular Vortices." Professor Rankine was not only the most eminent Professor of Engineering known in Great Britain, but he was also distinguished for his knowledge of pure science. His merit as a man of science was recognised by the British Association when he was chosen to be president, once of their mathematical, and twice of their mechanical sections. Glasgow University has by the death of this eminent man lost one of her most useful professors, so that in many quarters the utmost regret will be felt at his death. The Very Rev. Dean Edward Bannerman Ramsay was an M.A., an LL.D., and Fellow of our Society. In the years 1828 and 1829 he was one of the secretaries of our ordinary meetings, and in the years 1859 to 1861, he was one of our vice-presidents. In the year last named, at the special request of the council, he gave an opening address from this chair on the commencement of the winter session, which address was published in our Proceedings. The only paper read by him to the Society on a particular subject was a biographical memoir of the Rev. Dr Chalmers, with whom he had been on terms of friendship; and the memoir was published in our Transactions. I may add, that one of the last public acts of the Dean, other than professional, was to convene a meeting in this city, to obtain funds for a monument to Dr Chalmers, and this movement, I may add, proved so successful, that as the result of it, a colossal statue of that eminent man is now being executed, and will soon, I hope, adorn one of the principal streets of our city. This is neither the occasion nor the place for referring to Dean Ramsay's usefulness and reputation as a divine, or as a pastor of a large and attached congregation. Neither can I do more here than allude to the many excellent discourses and treatises on religious subjects, of which he was the author. But I cannot forbear mentioning, and with special emphasis, the Dean's geniality of disposition, his large-heartedness, and his entire freedom from sectarian jealousy, which enabled and disposed him to acccept, and even to seek, the society and friendship of any person of worth, though not belonging to his own branch of the Christian Church. May I be permitted to express a wish and entertain a hope that the example he set, approved of as it is by, I believe, all classes of this community, may not be without good effect. Dean Ramsay, though faithful and assiduous in the performance of his professional duties, found time for acquiring information and pursuing studies in other fields. He was extremely fond of music, and his knowledge of it, even in its scientific aspects, was well shown in two lectures which he delivered before the Philosophical Institution of the city "On the Genius and Works of Handel." His knowledge of botany was shown in a memoir which he published of the discoveries and works of his friend Sir J. E. Smith. But the literary work which carried his name farthest, and will preserve it longest, at least among his countrymen, was his "Reminiscences of Scottish Life and Character." It is a striking proof of the general appreciation of this book, that it went through twenty editions, and that only a fortnight before his death, the venerable Dean was revising the proof sheets of a twenty-first edition. Dean Edward Ramsay was a Scotchman of whom his country has reason to be proud, and who will live in the hearts of all who had the happiness to possess his personal acquaintance. Archibald Smith, of Jordanhill, was an LL.D. and F.R.S. of London and Edinburgh. He first distinguished himself as a student of Glasgow University, and afterwards in Cambridge, having, at Trinity College there, acquired the high position of Senior Wrangler and first Smith's prizeman. Though he became by profession an English barrister, his tastes were for mathematics and physics. He was employed by Government to make a reduction of important magnetic observations carried on by two Government ships in the Antarctic regions. He was employed at the suggestion of Sir Edward Sabine and Professor Airy, both of whom were well acquainted with his mathematical powers. The chief value of his services lay in his correcting the effect on the magnetic observations due to the iron in the ships. He afterwards, under the sanction of Government, drew up and published an "Admiralty Manual for the Deviation of the Compass," a work greatly appreciated, and which has been republished in various languages. Mr Smith received from the Royal Society of London one of its Royal Medals; from the Emperor of Russia, a beautiful compass set with diamonds; and from our own Government, a gift of L.2000, in acknowledgment of his important scientific services. The three individuals to whom I have now referred were each, in their different vocations, distinguished by high character, superior talents, and useful lives; and I am sure that all present will approve of the tribute of respect to their memory, which in name of the Council I have now, however imperfectly, attempted to offer.

The following Communications were read :—

1. On a Question of Arrangement and Probabilities.

By Professor Tait.

Many of the common illustrations of probabilities are taken from games in which each hand, or trick, *must* necessarily be won by one player, and lost by the other. It becomes an interesting question to inquire what modification is introduced if we contemplate the possibility of a hand, or trick, being drawn—*i.e.* not won or lost by either player. The only difficulty lies in taking account of the limiting conditions.

In the game of golf, for instance, where each hole separately may be won, halved, or lost, we have the following question. When a player is x holes "up," and y "to play," in how many ways may he win?

Let this number be represented by $P_{x,y}$. Then obviously

$$P_{x+1,y+1} = P_{x+2,y} + P_{x+1,y} + P_{x,y}.$$

If

$$P_{x,y} = a^x b^y$$

be a particular integral, we have

$$ab = a^2 + a + 1,$$

so that

$$P_{x,y} = \Sigma C a^x \left(a + 1 + \frac{1}{a}\right)^y.$$

Now the conditions are obviously

$$P_{x,y} = 1, \text{ if } x > y;$$

and

$$P_{-x,y} = 0, \text{ if } x \overset{=}{>} y.$$

Failing in several attempts to determine fully the special form of $P_{x,y}$ from these conditions, I had recourse to a graphical method, which will be given below. But before I do so, I take another mode of integration, which leads easily to special numerical results.

Suppose $y = x + n$,
then the equation becomes

$$\Delta P_{x,x+n} = P_{x+2,x+n} + P_{x+1,x+n}$$

from which it appears that if we can find expressions for $P_{x,x+m}$ and $P_{x+1,x+m}$ we can deduce by summation that for $P_{x-1,x+m}$.

Let us first put $n = 0$; we have

$$\Delta P_{x,x} = P_{x+2,x} + P_{x+1,x} = 2,$$

since, obviously, each of these quantities is unity. Integrating, we have

$$P_{x,x} = 2x,$$

no constant being added, since it is clear that

$$P_{0,0} = 0.$$

Again, by the fundamental equation, putting $n = 1$, we have

$$\begin{aligned} \Delta P_{x,x+1} &= P_{x+2,x+1} + P_{x+1,x+1} \\ &= 1 + 2(x+1) \\ P_{x,x+1} &= x + x(x+1) + C \\ &= (x+1)^2 = x(x+1) + (x+1) \end{aligned}$$

for we have obviously

$$P_{0,1} = 1\,.$$

Next,

$$\begin{aligned}\Delta P_{x,x+2} &= P_{x+2,x+2} + P_{x+1,x+2}\\ &= 2(x+2) + (x+2) + (x+1)(x+2)\,.\end{aligned}$$

$$P_{x,x+2} = \frac{3}{2}(x+1)(x+2) + \frac{1}{3}x(x+1)(x+2)\,,$$

no constant being added, for

$$P_{0,2} = 3\,.$$

Similarly,

$$P_{x,x+3} = \frac{5}{6}(x+1)(x+2)(x+3) + \frac{1}{2}(x+2)(x+3) + \frac{1}{12}x(x+1)(x+2)(x+3)\,,$$

for

$$P_{0,3} = P_{1,2} + P_{0,2} + P_{-1,2} = 4 + 3 + 1 = 8\,.$$

$$P_{x,x+4} = \frac{2}{3}(x+2)(x+3)(x+4) + \frac{7}{24}(x+1)(x+2)(x+3)(x+4) + \frac{1}{60}x(x+1)(x+2)(x+3)(x+4)$$

for

$$P_{0,4} = P_{1,3} + P_{0,3} + P_{-1,3} = 11 + 8 + 4 = 23.$$

We may now, in conformity with these expressions, assume

$$P_{x,x+n} = \left\{ A_n + \frac{B_n}{x} + \frac{C_n}{x(x+1)} + \ .\ \ .\ \ . \right\} x\,\overline{x+1}\ .\ \ .\ \ .\overline{x+n}$$

Now, if $y = x + n$, the original equation of differences gives

$$\Delta P_{x,x+n} = P_{x+2,x+n} + P_{x+1,x+n}$$

where Δ refers to x and *not* to n. By the assumed value of $P_{x,x+n}$ this becomes

$$\begin{aligned}&\left[\frac{(n+1)A_n}{x} + \frac{nB_n}{x(x+1)} + \frac{(n-1)C_n}{x(x+1)(x+2)} + \cdot\ \ \cdot\ \right] x\overline{x+1}\ \cdot\ \ \cdot\overline{x+n}\\ &= \left[A_{n-2} + \frac{B_{n-2}}{x+2} + \frac{C_{n-2}}{(x+2)(x+3)} + \cdot\ \ \cdot\ \right]\overline{x+2}\ \cdot\ \ \cdot\overline{x+n}\\ &+ \left[A_{n-1} + \frac{B_{n-1}}{x+1} + \frac{C_{n-1}}{(x+1)(x+2)} + \cdot\ \ \cdot\ \right]\overline{x+1}\ .\ \ .\ \overline{x+n}\end{aligned}$$

Whence, equating coefficients of like factorials, we have

$$\begin{aligned}(n+1)\,\mathrm{A}_n &= \mathrm{A}_{n-1}\,,\\ n\mathrm{B}_n &= \mathrm{B}_{n-1} + \mathrm{A}_{n-2}\,,\\ (n-1)\,\mathrm{C}_n &= \mathrm{C}_{n-1} + \mathrm{B}_{n-2}\,,\\ (n-2)\,\mathrm{D}_n &= \mathrm{D}_{n-1} + \mathrm{C}_{n-2},\ \text{\&c., \&c.}\end{aligned}$$

Let

$$\underline{|\,n+1}\,\mathrm{A}_n = a_n,\quad \underline{|\,n}\,\mathrm{B}_n = \beta_n\,,\quad \underline{|\,n-1}\,\mathrm{C}_n = \gamma_n,\ \text{\&c.}$$

then these equations become

$$\begin{array}{r|c|l} a_n = a_{n-1} & & a_n = \Sigma 0. \\ \beta_{n+1} = \beta_n + a_{n-1} & & \beta_n = \Sigma a_{n-1} = \dfrac{\Sigma}{\mathrm{D}}a_n \\ & \text{or} & \\ \gamma_{n+1} = \gamma_n + \beta_{n-1} & & \gamma_n = \Sigma\beta_{n-1} = \dfrac{\Sigma}{\mathrm{D}}\beta_n \\ \delta_{n+1} = \delta_n + \gamma_{n-1} & & \delta_n = \Sigma\gamma_{n-1} = \dfrac{\Sigma}{\mathrm{D}}\gamma_n,\ \text{\&c.} \end{array}$$

Thus we have

$$\mathrm{P}_{x,\,x+n} = \left\{\frac{a_n}{\underline{|\,n+1}} + \frac{\beta_n}{x\,\underline{|\,n}}\frac{\Sigma}{\mathrm{D}}a^n + \frac{1}{x(x+1)\,\underline{|\,n-1}}\left(\frac{\Sigma}{\mathrm{D}}\right)^2 a^n + \ldots\right\} x(x+1)\ldots(x+n)$$

$$= \left\{\quad a_n \quad + \frac{n+1}{x}\frac{\Sigma}{\mathrm{D}}a_n + \frac{n+1\,n}{x(x+1)}\left(\frac{\Sigma}{\mathrm{D}}\right)^2 a_n + \quad \ldots\right\}\frac{x(x+1)\ .(x+n)}{1.\,2\ \ldots(n+1)}$$

$$= \frac{1}{\left(\frac{\Sigma}{\mathrm{D}}\right)^{x-1}}\left\{\frac{\overline{x+n}\ldots\overline{n+2}}{1.2\ldots\overline{n-1}}\left(\frac{\Sigma}{\mathrm{D}}\right)^{x-1} + \frac{\overline{x+n}\ldots\overline{n+1}}{1.2\ldots\ldots n}\left(\frac{\Sigma}{\mathrm{D}}\right)^{x} + \ldots\ldots\right\} a_n$$

$$= \frac{\left(1+\frac{\Sigma}{\mathrm{D}}\right)^{x+n}}{\left(\frac{\Sigma}{\mathrm{D}}\right)^{x-1}}\ a_n\,,$$

for no negative powers of $\frac{\Sigma}{\mathrm{D}}$ are to be retained, as a_n is a mere constant.

The trouble of carrying out this process is considerable, depending on the determination of the constants in each finite integral so as to satisfy the limiting conditions of the problem. To a few terms we have

$$\mathrm{P}_{x,\,x+n} = \frac{\underline{|x+n}}{\underline{|x-1}\,\underline{|n+1}}\left\{2 + (2n-1)\frac{n+1}{x} + (n-2)^2\frac{(n+1)n}{x(x+1)} + \ldots\right\}.$$

By a slight modification of the preceding process we get in succession

$$\Delta\mathrm{P}_{-x,\,x+n} = \mathrm{P}_{-(x+1),\,x+n} + \mathrm{P}_{-(x+2),\,x+n}\,,$$

$${}_{-x,\,x+n} = \frac{\left(1+\frac{\Sigma}{\mathrm{D}}\right)^{x+n}}{\left(\frac{\Sigma}{\mathrm{D}}\right)^{x+1}}\,\alpha_n = \frac{\underline{|x+n}}{\underline{|x+1}\,\underline{|n-1}}\left\{1 + (n-1)\frac{n-1}{x+2} + \frac{(n-4)(x-1)}{2}\frac{(n-2)(x-1)}{(x+2)(x+3)} + \ldots\right\}.$$

The graphical method to which I referred above consists simply in supposing the various values of $\mathrm{P}_{x,\,y}$ to be written each at the point whose co-ordinates are the values of x and y. If, to fix the ideas, we suppose the axis of x to be horizontal and that of y vertically downwards, then the fundamental equation shows that *by adding together any three contiguous numbers in a horizontal line, we produce the number immediately under the middle one of the three.*

The limiting conditions show that all the numbers along the line

$$x + y = 0\,,$$

and those between it and the negative part of the axis of x, are zeros; while those along

$$y = x - 1\,,\ y = x - 2\,,\ y + x = 1\,,$$

are each equal to 1.

Hence we have the figure

$$\begin{array}{cccccccccccc}
0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \ldots\ldots x \\
0 & 0 & 0 & 0 & 0 & \mathbf{1} & \mathbf{2} & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \mathbf{1} & \mathbf{3} & \mathbf{4} & \mathbf{4} & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & \mathbf{1} & \mathbf{4} & \mathbf{8} & \mathbf{11} & \mathbf{9} & \mathbf{6} & 1 & 1 & 0 \\
0 & 0 & \mathbf{1} & \mathbf{5} & \mathbf{13} & \mathbf{23} & \mathbf{28} & \mathbf{26} & \mathbf{16} & \mathbf{8} & 1 & 1 \\
0 & \mathbf{1} & \mathbf{6} & \mathbf{19} & \mathbf{41} & \mathbf{64} & \mathbf{77} & \mathbf{70} & \mathbf{50} & \mathbf{25} & \mathbf{10} & 1 \\
 & & & & & \vdots & & & & & & \\
 & & \&c. & & & y & & & \&c. & & &
\end{array}
\qquad \cdot \quad \cdot \quad (a)$$

where the numbers printed in darker type are inserted by the rule given above. This is, of course, in one sense a complete solution of the problem; but the results may easily be put in an analytical form.

Had we had zeros along the line

$$y = x - 2$$

we should have had the following scheme instead of that above:

$$\begin{array}{ccccccccccccc}
 & & & & 0 & 1 & 0 & & . & . & & x & \\
 & & & 0 & \mathbf{1} & \mathbf{1} & 1 & 0 & & & & & \\
 & & 0 & \mathbf{1} & \mathbf{2} & \mathbf{3} & \mathbf{2} & 1 & 0 & & . & . & \qquad (b) \\
 & 0 & \mathbf{1} & \mathbf{3} & \mathbf{6} & \mathbf{7} & \mathbf{6} & \mathbf{3} & 1 & 0 & & & \\
0 & 1 & \mathbf{4} & \mathbf{10} & \mathbf{16} & \mathbf{19} & \mathbf{16} & \mathbf{10} & \mathbf{4} & 1 & 0 & & \\
 & & & & | & & & & & & & & \\
 & \&c. & & & y & & \&c. & & & & & &
\end{array}$$

Hence the part added by the units along the line

$$y = x - 2$$

is

$$\begin{array}{ccccccccccc}
 & & & 0 & & . & . & & x & & \\
 & & & 0 & 1 & & & & & & \\
 & & 0 & 1 & 1 & 2 & & & & & \\
 & 0 & 1 & 2 & 4 & 3 & 3 & & . & . & \qquad (c) \\
0 & 1 & 3 & 7 & 9 & 10 & 6 & 4 & & & \\
 & & & | & & & & & & & \\
 & & & y & & \&c. & & & & &
\end{array}$$

This, again, differs from (*b*) shifted one place downwards, by

$$\begin{array}{cccccccc}
0 & & . & . & & x & & \\
0 & 0 & & & & & & \\
0 & 0 & 1 & & & & & \\
0 & 1 & 1 & 2 & . & . & & \qquad (d) \\
1 & 2 & 4 & 3 & 3 & & & \\
y & & \&c. & & & & &
\end{array}$$

But it is obvious that this is a repetition of the same one place diagonally downwards to the right.

Also (b) is obviously the coefficients of the powers of a in

$$a\left(a+1+\frac{1}{a}\right)^{y}$$

for the several positive integral values of y. Call the term in a^{x} in this, *i.e.*, the coefficient of a^{x-1} in $\left(a+1+\frac{1}{a}\right)^{y}$, $A_{x,y}$, and that at x, y in the scheme (c) $Q_{x,y}$, then

$$Q_{x,y}-Q_{x-1,\,y-1}=A_{x,y-1}\,.$$

and thus

$$\begin{aligned}P_{x,y}&=A_{x,y}+Q_{x,y}\\&=A_{x,y}+A_{x,\,y-1}+A_{x-1,\,y-2}+\,.\;\;.\;\;.\;\;.\;\;.\;\;.\end{aligned}$$

This points to a very simple way of constructing the values of $P_{x,y}$ from those of $A_{x,y}$.

In scheme (b), add to the number in any position that immediately above it, and also those lying in the left handed upward diagonal drawn from the last named, their sum is the number in the corresponding position in (a). Thus $16+6+3+1=26$.

If D refer to x and D' to y, we have

$$\begin{aligned}P_{x,y}&=\left(1+\frac{1}{D'}+\frac{1}{DD'^{2}}+\frac{1}{D^{2}D'^{3}}+\dots\right)A_{x,y}\,,\\&=\left(1+\frac{D}{DD'-1}\right)A_{x,y}\,.\end{aligned}$$

It is to be observed that, since if one player wins the other must lose, $P_{-x,y}$ is the number of ways in which a player may lose, when he is x "up" and y "to play."

The number of ways in which the game may be drawn is also a solution of the same equation of differences; but the limiting conditions are now obviously independent of the sign of x: and are, taking it positive,

$$\begin{aligned}P_{x,y}&=1 \text{ if } x=y\,,\\P_{x,y}&=0 \text{ if } x>y\,.\end{aligned}$$

Hence the values are represented by the following scheme—

$$\begin{array}{cccccccccc}
 & & & 0 & 1 & 0 & . & . & . & x \\
 & & 0 & 1 & 1 & 1 & 0 & & & \\
 & 0 & 1 & 2 & 3 & 2 & 1 & 0 & & \\
0 & 1 & 3 & 6 & 7 & 6 & 3 & 1 & 0 & \\
 & & \&c. & & y & & \&c. & & &
\end{array}$$

Thus the value of $P_{x,y}$ in this case is the coefficient of a^x in

$$\left(a + 1 + \frac{1}{a}\right)^y.$$

Hence the number of different modes in which the game may finish, when one of the players is x "up," and there remains y "to play" is, calling $R_{x,y}$ the coefficient of a^x in $\left(a + 1 + \frac{1}{a}\right)^y$,

$$\left[\left(D + \frac{1}{D}\right)\left(1 + \frac{D}{DD' - 1}\right) + 1\right] R_{x,y},$$

while the number of different ways of finishing if the whole y holes are played out is 3^y.

There are many very curious properties of the numbers we have denoted by $P_{x,y}$, $A_{x,y}$, $Q_{x,y}$. Thus, for instance, it is easy to see that

$$\begin{array}{ll}
Q_{1,2} = Q_{2,2} - 1 \qquad & Q_{0,2} = Q_{3,2} + 1 \\
Q_{1,3} = Q_{2,3} + 1 \qquad & Q_{0,3} = Q_{3,3} - 1
\end{array} \quad \&c.$$

all of which are included in

$$Q_{x,y} = Q_{3-x,y} + (-1)^{x+y}.$$

2. Laboratory Notes. By Professor Tait.

1. On the Stiffness of Wires.

The following are the results of some experiments made for me by Mr W. M. Ogilvie with Amontons' apparatus; chiefly with the view of testing the accuracy with which it can be applied, but incidentally with the view of obtaining an idea of the relation between tension and stiffness in the same wire or cord.

(*a*) Fine Iron Wire.

Weight on each end of Wire.	Weight required to overcome stiffness of Wire.
4,000 grains	170 grains
5,000 „	200 „
7,000 „	230 „
12,000 „	270 „
15,000 „	280 „
22,000 „	300 „

Roller used is 1½ in. diameter.

(*b*) Fine Copper Wire, annealed over a gas flame.

1000 grains	27 grains
2000 „	40 „
3000 „	50 „
4000 „	56 „
5000 „	60 „
8000 „	64 „

The results which immediately follow were obtained from annealed and unannealed wires, of the same gauge, of two very different kinds of copper—crown being of very high, C of very low, thermal and electric conductivity.

(*c*) Soft C Wire.

5,100 grains	1240 grains
9,100 „	1300 „
22,100 „	1370 „
40,100 „	1400 „

(*d*) Soft Crown Wire.

5,100 grains	1340 grains
9,100 „	1400 „
22,100 „	1500 „
40,100 „	1560 „

(*e*) Hard C Wire.

5,100 grains	1400 grains
12,100 „	1540 „
22,100 „	1740 „
41,100 „	1900 „

(*f*) Hard Crown Wire.

Weight on each end of Wire.	Weight required to overcome stiffness of Wire.
5,100 grains	1500 grains
9,100 "	1600 "
22,100 "	1800 "
40,100 "	2000 "

(*g*) Same Wire as (*e*), after several experiments with it.

10,000 grains	1340 grains
30,000 "	1600 "
50,000 "	1800 "
60,000 "	1900 "

(*h*) Soft Wire, another specimen of (*d*), after a good number of trials, and taking the average of the last three.

10,000 grains	1000 grains
30,000 "	1190 "
50,000 "	1360 "
60,000 "	1460 "

(*k*) Same Wire as last *doubled.*

10,000 grains	2300 grains	No great precautions were taken in this experiment to secure the weight being equally distributed over both wires.
30,000 "	2470 "	
50,000 "	2640 "	
60,000 "	2740 "	

No proper results could be got by *doubling* any of the unannealed wires.

(*l*) Whip Cord.

10,000 grains	130 grains
20,000 "	240 "
30,000 "	400 "
40,000 "	530 "
50,000 "	630 "
60,000 "	700 "

With one exception these results indicate a logarithmic relation between the stiffness (S) and the tension (T) of the form

$$S_0 - S \propto a^{-T}.$$

Here S_0 is the stiffness when the tension is very great.

Thus, taking the numbers in experiments (*b*) and (*l*) above, we obtain the following comparison with experiment of the formulæ—

$$68 - S = 61{\cdot}5 \times \left(\tfrac{2}{3}\right)^{\frac{T}{1000}}.$$

Experiment.	Formula.
41	41
28	27·3
18	18·2
12	12·1
8	8
4	2·4

$$1950 - S = 1987 \times (1{\cdot}08)^{-\frac{T}{10,000}}$$

Experiment.	Formula.
182	184
171	170
155	158
142	146
132	135
125	125

Considering the excessively uncertain nature of such experiments, these results may be looked upon as agreeing well with the law suggested.

2. Preliminary Sketch of the Thermo-electric Diagram for Iron, Gold, and Palladium.

3. On the Muscles which open and close the Mouth, with some Observations on the Active and Passive Condition of Muscles generally. By Dr Gamgee.

4. Observations and Experiments on the Cerebral Hemispheres and Corpora Striata of Birds. By Dr M'Kendrick. Communicated by Professor Turner.

Surgeon-Major Black exhibited twenty-five large photographic views of the late eruption of Mount Vesuvius, which had been executed by his brother, John Melton Black, Esq.

Monday, 20th January 1873.

SIR WILLIAM STIRLING MAXWELL, Bart.,
Vice-President, in the Chair.

The Council of the Royal Society have awarded the Makdougall Brisbane Prize to **George James Allman**, M.D., F.R.S., Emeritus Professor of Natural History in the University of Edinburgh, for his memoir "On the Homological Relations of the Cœlenterata," published in the Transactions of the Society for 1870–71.

In selecting this memoir for the prize, they took into consideration not merely its own importance as a contribution to zoological science, but the author's elaborate and beautifully illustrated monograph "On the Gymnoblastic or Tubularian Hydroids," published in two large folio volumes by the Ray Society, of which it forms a leading chapter.

This monograph comprises a most extensive series of researches into the morphology, development, minute structure, and physiology of an interesting group of invertebrated animals, as well as a careful consideration of their zoological position and classification.

It contains the observations and conclusions of many years of laborious research, and whilst serving as a memorial of the industry, artistic skill, and scientific acumen of its author, forms a most important contribution to natural history science.

The following Report was submitted to the Society:—

Report by the Council of the Royal Society of Edinburgh on the proposed alterations of the laws as to the Election of Ordinary Fellows:—

The Council have carefully considered the proposed alterations in the laws as to the election of Ordinary Fellows which were remitted to them by the Society for re-consideration on 3d June last, and have agreed to recommend to the Society that there should be no limitation in the number of Fellows annually elected, and that the following alterations should be adopted:—

That Laws IX. and XIII. should be altered as follows:—

IX.

Candidates for admission as Ordinary Fellows shall make an application in writing, and shall produce along with it a certificate of recommendation to the purport below,* signed by at least *four* Ordinary Fellows, two of whom shall certify their recommendation from personal knowledge. This recommendation shall be delivered to the Secretary, and by him laid before the Council, and shall afterwards be printed in the circulars for three Ordinary Meetings of the Society, previous to the day of election, and shall lie upon the table during that time.

XIII.

The election of Ordinary Fellows shall only take place at the first Ordinary Meeting of each month during the Session. The election shall be by ballot, and shall be determined by a majority of at least two-thirds of the votes, provided twenty-four Fellows be present and vote.

The Society adopted these alterations of the Laws.

The following Communications were read:—

1. On the Physical Constants of Hydrogenium. I.

By Mr James Dewar.

2. On the supposed Upheaval of Scotland, in its Central Parts, since the time of the Roman Occupation By D. Milne Home, LL.D.

No abstract of this paper is given in the Proceedings, as the paper will appear in the Transactions.

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* "A. B., a gentleman well-skilled in Science (*or Polite Literature, as the case may be*), being to our knowledge desirous of becoming a Fellow of the Royal Society of Edinburgh, we hereby recommend him as deserving of that honour, and as likely to prove a useful and valuable Member."

Monday, 3d February 1873.

SIR ROBERT CHRISTISON, Bart., President, in the Chair.

The following Communications were read:—

1. On the Anatomy of a new Species of Polyodon, the *Polyodon gladius* of Martens, taken from the river Yang-tsze-Kiang, 450 miles above Woosung. Part I., being its *External Characters and Structure.* By P. D. Handyside, M.D.

The position of this new species of Ganoid, under our commonly accepted classification, the author gave as follows:—

Division	Vertebrata.
1st primary section,	Ichthyopsida.
1st class,	Pisces.
3d sub-class,	Ganoidei.
2d order,	Chondrostei.
1st family,	Acipenseridæ.
2d family,	Polyodontidæ.
Genus,	Polyodon.
1st species,	P. folium.
2d species,	P. gladius.

After referring to the Polyodon *folium* of Lacépède (the *P. reticulata* of Shaw, the *Planirostra spatula* of Owen), the paddle-fish or spoon-bill sturgeon of the Ohio and Mississippi and their tributaries, as a well-known species of the genus in question, Dr Handyside went on to state that the new species now to be described was first observed on a Chinese fishmonger's stall at Woosung, 12 miles from Shanghai, and had since been found in the Yang-tsze-Kiang, and, as was alleged, in the northern Japanese sea. He then sketched the history of the Polyodontidæ family, and narrated the researches of Lacépède, Von Martens, Blakiston, Kaup, and Duméril.

He next exhibited to the Society—*first*, a small entire specimen of the *P. gladius*, measuring 26½ inches = 652 millimeters; *secondly*, an opened specimen measuring 40 inches = 1070 millimetres; *thirdly*, three pieces of an adult fish that measured fully 9 feet long = 2720 millimetres; and *fourthly*, a piece of an almost adult fish that was not measured. He showed also four large drawings, and twenty-four smaller ones (including nineteen microscopic views), illustrative of his description of the EXTERNAL CHARACTERS AND STRUCTURE of the fish, under the ten following heads:—

1st, Its size, weight, &c.; 2d, its form; 3d, its surface and colour; 4th, its fins; 5th, its proportional parts; 6th, its lateral line and system of muciparous pores; 7th, its exo- or dermo-skeleton and tegumentary system; 8th, its spatula, rostrum, or snout; 9th, its eyes, mouth, and teeth; and 10th, its branchiæ, pseudobranchiæ, and spiracula.

In the course of his paper, the author remarked that a specimen had been seen by Mr H. G. Hollingworth, resident at Kiu-Kiang, on the same river, reaching to the length of 15 feet, and weighing 133 lbs.; that in regard to edible properties, the young fish was said to be very delicate eating; that the body was compressed, elongated, and tapering towards the tail, like the sturgeon family generally. The head was projected beyond the mouth into an elongated muzzle or spatula. This snout was thin at the margins, but thick and keeled in the centre; in young specimens it was sharp at the point, but it afterwards got blunted and rounded off by digging among the silt of the river bottom. The eyes of the fish were of very small size, and it was supposed that the sensibility of the spatula compensated for the want of larger ones.

The 2d Part of Dr Handyside's paper will consist of an anatomical description of the nervous and muscular systems; the 3d Part of the viscera of organic life; and the 4th Part of the articular system and the endo-skeleton of the *Polyodon gladius*.

2. Note on the Thermal Equivalents of the Oxide of Chlorine. By James Dewar, Esq.

Two years ago the author submitted to the British Association a preliminary report on the subject, which has not been prosecuted, owing to the exhaustive investigations of Professor Thomsen of Copenhagen, on thermal values. In the paper referred to, the results are calculated on the assumption of hydriodic acid evolving 15,000 heat units for equivalent in aqueous solution. The above number is much too high, according to Thomsen's recent experiments, who gave 13,170 as the true number. If my former results are recalculated with the new value for hydriodic acid, the following numbers are obtained:—

Formation of Iodic acid in aqueous solution = 25,000 heat units.
„ Chlorine „ „ – 18,000 „
„ Peroxide of chlorine „ = – 9,800 „
„ Chlorous acid „ = – 21,000 „
„ Hypochlorous acid „ = – 28,000 „
(Thomsen.)

These results show clearly that the stability of the series increases as we ascend, and not the reverse, as has been generally supposed, from the thermal values obtained by Favre. No known series of bodies, therefore, diminishes in stability, or has a regular increment of absorption.

3. On the Resemblances which Microscopic Objects in Dichroite and Amethyst have to some of the lower forms of Organic Life. By J. Scott, Tain. Communicated by Professor Kelland.

When examining with the one inch object-glass of a compound microscope some pieces of Strathpeffer Albert coal, I happened to place on the stage a crystal of dichroite, and was surprised to observe its surface covered with circular impressions. Their resemblance to some which I had previously noticed on iron pyrites associated with Albertite, led to a further inspection, which showed that they were due to globular bodies of various colours distributed throughout the crystal in layers parallel to the respective faces.

By means of sections cut parallel to these faces, I observed that the lower side of each layer, namely, that looking towards the interior of the crystal, differs essentially in its structural peculiarities from the upper. On that side each object has a conical form like a limpet shell, and usually consists of three or four easily defined zones surrounding a well-marked central apex. With higher optical powers a greater number of segmentary zones are brought out, and radial and transverse striæ in exquisite detail.

Besides these individual characteristics, they exhibit composite relations of a peculiar kind, but in reality the development of a very simple principle. Whenever an increase of size has produced the contact of two or more individuals of a group, further enlargement has taken place by the formation of a common investing border.

From the deposition of the objects in successive layers, with their conical extremities resting on what had been at some stage of the crystal's formation one of its faces, they must have obtained their position whilst the crystal was in the act of formation.

Sections, either perpendicular or at an oblique angle to a face of the crystal, by presenting a side view of the objects, show that the hemispheroidal upper and the conical lower extremities were generally connected by a cylindrical body, whose comparative length varied considerably in the different individuals.

The same sections also exhibit a remarkable structural relation between the superimposed layers which occupy the successive laminæ of the crystal. When the objects can be traced from the interior towards the surface, they are found to have a linear arrangement symmetrically round axes perpendicular to the respective faces. These structural features can be well observed in sections through the terminal pyramid of some specimens of amethyst, in which they constitute a number of groups equal to the sides of the pyramid, each group consisting of a series of highly ornate beaded columns perpendicular to the same plane, and therefore parallel to one another.

The individual objects in the same axial line or column are often joined so closely that they may be considered as segments of a continuous whole, but in other instances the connection is a mere microscopic filament. In parts of the crystal a whole series of columns terminates on the same lamina, where the last segment of each has spread out to an extent which gives the structure the appearance of a disc with a long beaded handle attached to its centre. This last circumstance indicates one or both of two conditions—a period of retardation in the increase of the crystal, or of rapid acceleration in the growth of the objects. Irrespective of the structural features which the individual objects possess, their mode of succession in linear directions perpendicular to the planes of the crystal displays a conformity to law, which could not have resulted from any chance deposition of coloured particles, whether solid or liquid, on the surface of the crystal during the process of formation. They must therefore belong to some peculiar crystalline form, or to some order in the organic world.

The mode of aggregation just described has obviously a close resemblance to some of those animal structures produced by continuous gemmation, as for instance some of the compound Foraminifera.

But the agreement between the objects and organic bodies is not confined to form and other structural resemblances—it extends to the changes through which they must have passed before they were enclosed in the substance of the crystal. Whatever their original nature, so completely have they become impregnated with the inorganic elements of the crystal, that the more opaque layers are often viewed through the silicified casts of their successors. Before, however, their condition became thus permanently fixed, there is evidence of continued and varied change. Specimens of amethyst contain whole layers from which the upper or globular end of each object has entirely disappeared, and their interior become occupied with silica so transparent that the delicate structural features of the conical extremity can be equally well seen when viewed on either side by transmitted light. In other instances nothing remains except portions of concentric annuli.

The objects that retain their structural features most entire are opaque, and as seen in a small section of dichroite appear of a brilliant white on the lower side, and of a somewhat silvery lustre on the upper. The same section also exhibits the changes on the external envelope, including its partial and complete removal. In one group it has disappeared from the one side, while it remains quite entire on the other, producing a well-marked boundary line, which passes over many of the individual objects, displaying in striking contrast the difference between the outside shell and the matter of the interior. Whenever divested of this covering, as is generally the case, the bodies are seen to be in groups of various colours, namely, red, orange, yellow, browns of various tints, and dark blue.

4. Note on the Zodiacal Light. By George Forbes, Esq.

A peculiarity was observed about the vernal equinox in 1871 in the shape of the zodiacal light, which deserves to be recorded. The appearance resembled a thin cone (such as is usually seen), extending to a great height, and rising out of a broad low cone situated at its base. This was not an effect of sunlight, for it was visible hours after sunset. It was not peculiar to any time or place, for it was seen constantly in all parts of the south of Europe, viz., in the Bay of Biscay, all along the Mediterranean, in Malta, and in Sicily. It seems not unlikely that there are periodic changes in the appearance of the zodiacal light. Hence it is well to mention any such peculiarity. I have also to confirm what has so often been stated by other observers, that the direction of the axis of the cone is not always in the direction of the ecliptic, but changes its direction from night to night.

Monday, 17th February 1873.

Sir ROBERT CHRISTISON, Bart., President,
in the Chair.

The following Communications were read :—

1. Note on Ångström's Method for the Conductivity of Bars. By Professor Tait.

If we assume the excess of temperature above that of the air, v, to be the same throughout a transverse section of the bar, the equation for the flux of heat is—

$$\frac{dv}{dt} = \frac{1}{c\rho}\frac{d}{dx}\left(k\frac{dv}{dx}\right) - \frac{4h}{ac\rho}v ,$$

where $c\rho$ is the water equivalent of unit volume of the bar, k its thermal conductivity, a its side, and hv the quantity of heat lost by radiation and convection from unit surface of the bar per unit of time, when the excess of temperature is v.

Ångström writes this in the form—

$$\frac{dv}{dt} = K\frac{d^2v}{dx^2} - Hv\,,$$

assuming the conductivity to be unaffected by temperature, so that it is necessary that the range of temperature in his experiments be small. As the method consists essentially in so applying the heat as to bring the bar to a *periodic* state of temperature at each point, the solution must be of the form—

$$v = V + \Sigma_1^\infty A_n \epsilon^{-p_n x} \cos\left(n\frac{2\pi t}{T} - q_n x + \beta_n\right),$$

where T is the period, and V is the mean temperature or non-periodic part of the solution. Substituting in the equation, we have—

$$0 = K\frac{d^2V}{dx^2} - HV\,,$$

$$-\frac{2\pi n}{T} = -2Kp_nq_n\,,$$

$$0 = K(p_n^2 - q_n^2) - H\,.$$

The second of these is equivalent to Ångström's exceedingly simple expression for K in terms of the experimental data. Ångström, however, goes farther than this, for instead of the formula for v just given, he uses a more restricted one, which assigns very simple forms for the quantities p_n, q_n, viz.,—

$$p_n = g\sqrt{n}, \qquad q_n = g'\sqrt{n}\,,^*$$

where g and g' are absolute constants, depending on K, H, T alone. If this were admissible, it seems that we should have not only, with Ångström,

$$\frac{\pi}{T} = Kgg'\,;$$

but also the impossible relation,

$$0 = Kn\,(g^2 - g'^2) - H\,,$$

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* There are several serious misprints, both in the original (*Pogg.* 1862) and in the English translation (*Phil. Mag.* 1863, I.) In fact, in the expression for v, $\sqrt{x}$ appears instead of x, alike in the exponential and in the argument of the cosine.

where all the quantities are constants except n, which may be *any* positive integer.

It is obvious that, as the difference of the squares of p_n, q_n, is constant, while their product varies as n, their values will ultimately be *equal* for very great values of n. We may therefore assume, as an approximation, for large values of n—

$$p_n = \sqrt{\frac{\pi n}{\mathrm{KT}}}(1+e)\,,\quad q_n = \sqrt{\frac{\pi n}{\mathrm{KT}}}(1-e)$$

where the square of e is negligible. This satisfies the first of our conditions, and the second gives

$$e = \frac{\mathrm{HT}}{4\pi n}\,.$$

This remark does not, of course, affect Ångström's deduction of the conductivity from the term of full period; but it must materially affect the others, and thus it is certainly remarkable how closely the results he has obtained from the second and third harmonic terms agree with these simple forms.

I have not as yet managed to control by this process my results deduced by Forbes's method (*Trans. R.S.E.*), though I hope soon to do so The difficulties are of two kinds: 1*st*, in the strictly periodic application of very hot sources, without a great range; 2*d*, in the procuring of thermometers which will give with great accuracy small differences at very high temperatures. In the meantime, with the assistance of several of my laboratory students, especially Messrs Greig and M'Leish, I have studied the periodic state of temperature in bars of copper (of two very different kinds), iron, and German silver, produced by applying for fifteen minutes at a time, and with fifteen minute intervals, a powerful Bunsen burner to one end. The ranges of temperature thus produced are so great that the differential equation assumed above can hardly be regarded as even a rough approximation to the law of the phenomenon. Still, the results possess considerable interest, especially in the contrast between the various substances; indicating the great differences not merely in conducting power, but also in its rate of change with temperature The bars employed were all 1¼-inch square, and the thermometers were inserted at 3-inch intervals.

COPPER—C.

High Temperature.

I.	II.	III.	IV.
100 +	100 +	90 +	80 +
4·3	1·55	7·8	11·6
29·1	7·2	5·3	6·6
58·6	26·9	16·	10·7
78·7	43·	28·5	18·6
91·8	55·5	38·8	26·8
68·	51·4	41·6	32·1
41·	32·6	31·7	28·5
21·2	16·7	20·2	21·4

A_0 = 149·087	A'_0 = 129·33	A''_0 = 113·737	A'''_0 = 99·537
A_1 = − 38·916	A'_1 = − 25·95	A''_1 = − 15·634	A'''_1 = − 7·813
B_1 = 7·688	B'_1 = − 4·589	B''_1 = − 8·874	B'''_1 = − 9·453
α_1 = 39·668	α'_1 = 26·3524	α''_1 = 17·977	α'''_1 = 12·263
β_1 = 168°·83	β'_1 = 190°·02	β''_1 = 209°·57	β'''_1 = 230°·42
A_2 = − 0·875	A'_2 = − 0·612		
B_2 = − 0·7	B'_2 = − 0·275		
α_2 = 1·12	α'_2 = 0·68		
β_2 = 218°·65	β'_2 = 240°·12		
A_3 = − 4·834	A'_3 = − 1·025		
B_3 = − 1·112	B'_3 = − 1·74		
α_3 = 4·96	α'_3 = 2·02		
β_3 = 192°·95	β'_3 = 239°·49		

$\frac{\alpha_1}{\alpha'_1}$ = 1·5052	$\Delta\beta_1$ = 21°·19
$\frac{\alpha'_1}{\alpha''_1}$ = 1·4658	$\Delta\beta'_1$ = 19°·55
$\frac{\alpha''_1}{\alpha'''_1}$ = 1·4659	$\Delta\beta''_1$ = 20°·85
$\frac{\alpha_3}{\alpha'_3}$ = 2·455	$\Delta\beta_3$ = 46°·44

COPPER—C.

Low Temperature.

I.	II.	III.	IV.
40 +	40 +	40 +	40 +
32·4	21·	12·15	5·
27·	20·6	13·9	7·1
18·7	15·7	11·45	6·65
12·5	10·8	8·	4·5
7·55	6·8	5·	2·4
13·55	7·3	3·65	·6
22·5	12·9	6·5	1·35
29·	18·1	10·05	3·7

A_0 = 60·4	A'_0 = 54·25	A''_0 = 48·83	A'''_0 = 43·91
A_1 = 11·507	A'_1 = 7·1915	A''_1 = 3·9618	A'''_1 = 1·6576
B_1 = − 1·489	B'_1 = 1·7606	B''_1 = 2·687	B'''_1 = 2·6154
α_1 = 11·603	α'_1 = 7·4038	α''_1 = 4·787	α'''_1 = 3·097
β_1 = 352°·63	β'_1 = 373°·75	β''_1 = 394°·14	β'''_1 = 417°·63
A_2 = − ·3125	A'_2 = − ·2		
B_2 = − ·2375	B'_2 = − ·25		
α_2 = ·3925	α'_2 = ·335		
β_2 = 217°·24	β'_2 = 231°·34		
A_3 = ·918	A'_3 = − ·09156		
B_3 = ·4108	B'_3 = ·3606		
α_3 = 1·	α'_3 = ·372		
β_3 = 384°·10	β'_3 = 464°·25		

$\frac{\alpha_1}{\alpha'_1}$ = 1·5671	$\Delta\beta_1$ = 21°·12
$\frac{\alpha'_1}{\alpha''_1}$ = 1·5466	$\Delta\beta'_1$ = 20°·39
$\frac{\alpha''_1}{\alpha'''_1}$ = 1·5459	$\Delta\beta''_1$ = 23°·49
$\frac{\alpha_3}{\alpha'_3}$ = 2·688	$\Delta\beta_3$ = 80°·15

COPPER—CROWN.

High Temperature.

I.	II.	III.	IV.
100 +	100 +	80 +	80 +
64·1	55·5	53·5	37·8
36·2	34·4	39·4	30·2
16·6	17·7	25·7	19·8
2·2	4·	14·2	10·2
32·	15·	15·3	6·6
60·	36·2	29·3	14·6
79·1	53·1	43·	24·6
92·6	65·1	54·	33·6

$A_0 =$ 147·85	$A'_0 =$ 135·285	$A''_0 =$ 114·3	$A'''_0 =$ 102·15
$A_1 =$ 19·798	$A'_1 =$ 20·696	$A''_1 =$ 18·371	$A'''_1 =$ 14·694
$B_1 = -$ 35·8127	$B'_1 = -$ 20·05	$B''_1 = -$ 9·5398	$B'''_1 = -$ 2·58
$\alpha_1 =$ 40·9152	$\alpha'_1 =$ 28·8153	$\alpha''_1 =$ 20·7006	$\alpha'''_1 =$ 14·9187
$\beta_1 =$ 298°·94	$\beta'_1 =$ 315°·91	$\beta''_1 =$ 332°·56	$\beta'''_1 =$ 350°·05
$A_2 =$ ·1	$A'_2 = -$ ·075		
$B_2 =$ ·35	$B'_2 =$ ·375		
$\alpha_2 =$ ·47	$\alpha'_2 =$ ·382		
$\beta_2 =$ 74°·05	$\beta'_2 =$ 101°·57		
$A_3 = -$ 3·748	$A'_3 = -$ ·358		
$B_3 = -$ 4·563	$B'_3 = -$ 2·27		
$\alpha_3 =$ 5·905	$\alpha'_3 =$ 2·298		
$\beta_3 =$ 230°·65	$\beta'_3 =$ 261°·48		

$\frac{\alpha_1}{\alpha'_1} =$ 1·42	$\Delta\beta_1 =$ 16°·97
$\frac{\alpha'_1}{\alpha''_1} =$ 1·392	$\Delta\beta'_1 =$ 16°·65
$\frac{\alpha''_1}{\alpha'''_1} =$ 1·3875	$\Delta\beta''_1 =$ 17°·49
$\frac{\alpha_3}{\alpha'_3} =$ 2·455	$\Delta\beta_3 =$ 30°·83

COPPER—CROWN.

Low Temperature.

I.	II.	III.	IV.
40 +	30 +	30 +	30 +
·1	9·6	8·2	7·
7·2	12·	8·6	5·9
14·4	17·4	12·1	8·45
19·7	21·9	15·6	11·2
23·6	25·4	18·65	13·65
16·9	23·	18·7	13·7
9·65	17·7	15·	11·45
4·	13·	11·1	8·65

$A_0 =$ 51·94	$A'_0 =$ 47·5	$A''_0 =$ 43·49	$A'''_0 =$ 40·
$A_1 = -$ 10·365	$A'_1 = -$ 7·4678	$A''_1 = -$ 5·1934	$A'''_1 = -$ 3·492
$B_1 =$ 2·248	$B'_1 = -$ ·42123	$B''_1 = -$ 1·715	$B'''_1 = -$ 1·678
$\alpha_1 =$ 10·606	$\alpha'_1 =$ 7·5856	$\alpha''_1 =$ 5·4692	$\alpha'''_1 =$ 3·874
$\beta_1 =$ 167°·76	$\beta'_1 =$ 183°·22	$\beta''_1 =$ 198°·27	$\beta'''_1 =$ 205°·66
$A_2 = -$ ·0875	$A'_2 = -$ ·025		
$B_2 =$ ·1	$B'_2 = -$ ·025		
$\alpha_2 =$ ·132	$\alpha'_2 =$ ·035		
$\beta_2 =$ 131°·19	$\beta'^{2} =$ 135°·0		
$A_3 = -$ 1·38	$A'_3 = -$ ·432		
$B_3 = -$ ·127	$B'_3 = -$ ·296		
$\alpha_3 =$ 1·39	$\alpha'_3 =$ ·523		
$\beta_3 =$ 185°·25	$\beta'_3 =$ 214°·42		

$\frac{\alpha_1}{\alpha'_1} =$ 1·398	$\Delta\beta_1 =$ 15°·46
$\frac{\alpha'_1}{\alpha''_1} =$ 1·387	$\Delta\beta'_1 =$ 15°·05
$\frac{\alpha''_1}{\alpha'''_1} =$ 1·412	$\Delta\beta''_1 =$ 7°·39
$\frac{\alpha_3}{\alpha'_3} =$ 2·663	$\Delta\beta_3 =$ 29°·17

IRON.

I.	II.	III.	IV.
130+	110+	80+	70+
16·2	6·6	10·	2·6
35·1	9·7	7·9	·9
52·3	17·	9·3	·1
65·65	24·5	12·3	·7
62·	29·9	15·85	2·1
41·5	28·1	17·7	3·6
25·	21·	16·9	4·1
8·2	12·5	13·85	3·7

$A_0 =$ 168·24	$A_0 =$ 128·66	$A_0 =$ 92·95	$A_0 =$ 72·225
$A_1 = -$ 22·737	$A_1 = -$ 11·1989	$A_1 = -$ 2·921	$A_1 =$ ·178
$B_1 =$ 15·85	$B_1 = -$ 2·1312	$B_1 = =$ 3·906	$B_1 = -$ 2·007
$\alpha_1 =$ 27·7161	$\alpha'_1 =$ 11·49	$\alpha''_1 =$ 4·8773	$\alpha'''_1 =$ 2·015
$\beta_1 =$ 145°·12	$\beta'_1 =$ 190°·77	$\beta''_1 =$ 233°·20	$\beta'''_1 =$ 275°·07
$A_2 =$ ·225	$A_2 = -$ ·375		
$B_2 =$ ·68	$B_2 =$ ·2		
$\alpha_2 =$ ·716	$\alpha'_2 =$ ·425		
$\beta_2 =$ 71°·69	$\beta'_2 =$ 151°·93		
$A_3 = -$ ·163	$A_3 = -$ ·451		
$B_3 =$ 2·2	$B_3 = -$ ·1314		
$\alpha_3 =$ 2·21	$\alpha'_3 =$ 1·47		
$\beta_3 =$ 94°·24	$\beta'_3 =$ 196°·24		

$\frac{\alpha_1}{\alpha'_1} = 2{\cdot}413$ $\Delta\beta_1 = 45^\circ{\cdot}65$

$\frac{\alpha'_1}{\alpha''_1} = 2{\cdot}335$ $\Delta\beta'_1 = 42^\circ{\cdot}43$

$\frac{\alpha''_1}{\alpha'''_1} = 2{\cdot}421$ $\Delta\beta''_1 = 41^\circ{\cdot}87$

GERMAN SILVER.

I.	II.	III.	IV.
120+	100+	70+	
79.4	39·1	13·8	60·
53·5	34·6	16·4	59·
29·6	25·5	15·45	57·3
10·2	14·5	11·9	55·7
20·7	6·5	7·1	55·15
48·5	9·5	4·1	56·05
73·1	20·	4·8	57·65
91·65	32·	8·4	59·3

$A_0 =$ 170·83	$A_0 =$ 122·71	$A_0 =$ 80·24	$A_0 =$ 57·52
$A_1 =$ 29·957	$A_1 =$ 15·6806	$A_1 =$ 3·2304	$A_1 =$ 2·37
$B_1 = -$ 24·39	$B_1 =$ 2·7185	$B_1 =$ 5·4555	$B_1 = -$ ·2024
$\alpha_1 =$ 38·63	$\alpha'_1 =$ 15·915	$\alpha''_1 =$ 6·340	$\alpha'''_1 =$ 2·378
$\beta_1 =$ 320°·85	$\beta'_1 =$ 368°·84	$\beta''_1 =$ 419°·37	$\beta'''_1 =$ 475°·12
$A_2 = -$ ·65	$A_2 =$ ·025		
$B_2 =$ ·0375	$B_2 = -$ ·6		
$\alpha_2 =$ ·651	$\alpha'_2 =$ ·6		
$\beta_2 =$ 176°·7	$\beta'_2 =$ 358°·62		
$A_3 = -$ ·607	$A_3 =$ ·62		
$B_3 = -$ 2·64	$B_3 = -$ ·0315		
$\alpha_3 =$ 2·708	$\alpha'_3 =$ ·62		
$\beta_3 =$ 256°·75	$\beta'_3 =$ 357°·1		

$\frac{\alpha_1}{\alpha'_1} = 2{\cdot}427$ $\Delta\beta_1 = 48^\circ$

$\frac{\alpha'_1}{\alpha''_1} = 2{\cdot}510$ $\Delta\beta'_1 = 50^\circ{\cdot}53$

$\frac{\alpha''_1}{\alpha'''_1} = 2{\cdot}665$ $\Delta\beta''_1 = 55^\circ{\cdot}75$

The thermometers were read once a minute when the periodic state was arrived at, the corresponding curves were traced; and from the curves so drawn, eight values of the temperature were deduced for successive intervals of three and three-quarter minutes. It was easy from these to calculate the coefficients of the harmonic terms up to the fourth inclusive, in the following expression—

$$v = A_0 + A_1 \cos \frac{2\pi}{T} t + A_2 \cos 2 \frac{2\pi}{T} t + \ldots$$

$$+ B_1 \sin \frac{2\pi}{T} t + B_2 \sin 2 \frac{2\pi}{T} t + \ldots \quad .$$

From these again were calculated sets of values of α and β by the formulæ

$$\alpha = \sqrt{A^2 + B^2}, \ \tan \beta = \frac{B}{A} .$$

In the preceding tables the dashes refer to the position on the bar, the suffixes to the order of the harmonic. It will be seen that the co-efficients of the even harmonics are too small to give any trustworthy results.

As the thermometers were read *successively* by one observer, the whole process occupying twenty seconds or $\frac{1}{90}$ of a period, the values of the phase must be diminished by 0°, 1°, 2°, 3°, respectively, *i.e.*, the differences of phase must each be diminished by 1°.

2. On the Thermal Conductivity of Ice, and a new Method of Determining the Conductivity of Different Substances.

By Professor George Forbes.

The value of the coefficient of conductivity for ice is an important desideratum in several branches of physics; and it derives additional importance from an application, explained in the second part of this communication, to the determination of the thermal conductivity of different substances in absolute measure. The brilliant researches of Neumann,* and some ingenious experiments by M. Lucien De La Rive,† afford us at present the only two determinations that we possess of this important quantity. The value found by Neumann is 0·114, while De La Rive makes it 0·138. The discrepancy justifies the publication of experiments on a somewhat large scale, which gives us a close approximation to the truth.

Sir William Thomson suggested the method of imitating the freezing of a lake by means of a freezing mixture, and to deduce the conductivity from measures of the thickness of the ice formed in a definite time. In order to carry out this idea, I ordered an apparatus to be constructed by means of which a disc of ice could be formed twelve inches in diameter by a freezing mixture placed above a vessel of water kept constantly at 0° C. A means was devised for measuring the thickness of ice formed at successive intervals of time. The freezing mixture was drained constantly during the course of each experiment by means of a syphon. Temperature was read frequently at the base of the vessel in which it was contained. It was found possible to read the thickness of ice formed to within $\frac{1}{80}$th of an inch. The experiments lasted from four or five hours to twenty-one hours, a watch being kept continually on the drainage and temperature of the mixture for the first six or eight hours in experiments of long duration. The ice formed was quite uniform, very clear, and when cloven by planes perpendicular to the plane of freezing, split easily, showing the crystalline structure with great clearness.

Six whole days of frosty weather were employed in perfecting and completing the series of observations, during which time seventy-two readings were taken, capable of giving a value for the conductivity;

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* Phil. Mag. 1863.

† Soc. de Ph. d'Hist. Nat. de Genève, 1864.

but the early determinations were rejected for obvious reasons, and the ultimate determination was made from a mean of fourteen readings, the experiments having been performed in this case with extraordinary care, and with all the experience derived from previous trials.

Let the heat required to raise 1 gramme of water 1° C. be taken as our unit of heat. Assuming that in the formation of the ice a statical state of temperature has been reached, we have

$$F = k\frac{\delta\theta}{x}$$

when $F =$ the flux of heat, $k =$ the coefficient of conductivity,
$\delta\theta = -$ (the temperature of the freezing mixture),
$x =$ the thickness of ice.

k is assumed to be the quantity of heat which crosses an area of ice 1 square centimetre section in 1 minute, the thickness of ice being 1 centimetre, and the difference of temperature of the two sides of the ice being 1° C.

But $F =$ the quantity of water raised 1° Cent., in 1 minute, over a surface of 1 sq. centimetre.

= (volume of ice formed in centimetres) × (latent heat of water) × (specific gravity of ice).

$$= \frac{dx}{dt} \cdot \text{S.L.}$$

$$\therefore\ k\frac{\delta\theta}{n} = \text{S.L.} \cdot \frac{dx}{dt}$$

$$\therefore\ k\ \delta\theta : t = \text{S.L.}\ \frac{x^2}{2}$$

or

$$k = \frac{\text{S.L.}\ x^2}{2\ \delta\theta \cdot t}.$$

Employing this formula in the series of experiments alluded to above as being worthy of the greatest confidence, fourteen values of k were found corresponding to different values of x. Now, for small values of x an error in the value of x will introduce an error into the value of k greater than for large values of x. The value of an observation is almost exactly proportional to x. After giving to each result a weight proportional to x, the mean thus obtained was

$$k = 0{\cdot}134.$$

This is given in terms of the units mentioned above, to which also Neumann's and De La Rive's results have been reduced. Other experiments confirmed this result when reduced in the same manner.

In the course of these experiments some facts were noted, which, though not belonging exactly to the subject of this communication, are yet worthy of being recorded.

1*st*, A number of measurements were made in the temperature of salt and fresh snow, mixed in different proportions, with the following results:—

4	parts (by weight)	of salt	+ 1	part of snow	gives	− 20°·3 C.
2	„ „	„	+ 1	„ „	„	− 21°·1
1	„ „	„	+ 1	„ „	„	− 21°·4
1	„ „	„	+ 2	„ „	„	− 21°·66
1	„ „	„	+ 3	„ „	„	− 21°·72
1	„ „	„	+ 4	„ „	„	− 21°·4

2*d*, The blocks of ice formed were frozen in a cylinder, with air above and water below. These blocks were cut out by means of a chisel and hammer. In spite of the great force used, there was not the slightest tendency in the ice to split when thus compressed by the walls of the containing vessel, although the finest point split the ice with great ease when the block had been cut out.

Having completed the investigation with respect to ice, it occurred to me to extend the same process by means of a slight modification to the conductivity of other substances. The method employed was as follows:—A tin canister of about 3 inches diameter was filled with a freezing mixture whose temperature was frequently read. This was placed above the substance to be examined, which itself was laid in a flat tin dish resting on supports in water cooled to 0° cent. If the substance examined were a powder or soft material like cotton wool, it was made to rise to the level of two pieces of glass laid on the flat dish. So soon as ice began to be formed, it was considered that the statical state of temperature was reached; accordingly the ice was then scraped off from the bottom of the flat dish, and the time noted. An experiment usually lasted about one hour. The thickness of the substance was measured and also that of the ice formed.

Let θ_1 be the temperature of the ice-cold water, θ_0 that of the freezing mixture, and θ that of the boundary between the substance examined and the ice formed.

Let x = the thickness of ice formed,
a = ,, substance examined,
k = conductivity of ice,
k_1 = ,, the other substance.

Then the flux of heat being F,

$$\mathrm{F} = k\frac{\theta - \theta_0}{a} = k_1\,\frac{\theta_1 - \theta}{x}$$

$$= \frac{\theta_1 - \theta_0}{\frac{a}{k} + \frac{x}{k_1}} = \frac{\delta\theta}{\frac{a}{k} + \frac{x}{k_1}}$$

Also, adopting the same notation as before,

$$\mathrm{F} = \frac{dx}{dt} \cdot \mathrm{S.L.}$$

$$\therefore \frac{\delta\theta}{\frac{a}{k} + \frac{x}{k_1}} = \frac{dx}{dt} \cdot \mathrm{S.L.}$$

$$\therefore \frac{t\delta\theta}{\mathrm{S.L.}} = \frac{a}{k}x + \frac{x^2}{2k_1} .$$

$$k = \frac{ax}{\frac{t\delta\theta}{\mathrm{S.L.}} - \frac{x^2}{2.k_1}} .$$

The last term in the denominator is always small for a non-conductor, and if ever it becomes large, we may be sure that this mode of experimenting is not available, since the temperature will not be in a permanent state.

In examining solid bodies, it is well to immerse the solid body itself in the water. Moreover, in this case I employed a convenient vessel to contain the freezing mixture, consisting of a funnel-shaped glass vessel, 4 inches diameter at the top and 3 inches at the bottom, and being open at the two ends; its narrow end was closed by a tightly-stretched membrane, thus securing good contact.

In this way a large number of bodies was examined, with following results :—

Ice, along ax. . =	·134
Ice, perp. to ax. =	·128
Black marble . .	·106
White marble . .	·0691
Slate . . .	·0486
Snow . . .	·0432
Cork . . .	·0430
Glass . . .	·0300
Pasteboard . .	·0272
Carbon . . .	·0243
Roofing felt . .	·0201
Firwood (parallel to fibre)	·0180
„ (across fibre and along the radius)	·00529
Boiler cement . .	·00975
Paraffin . . .	·00843
Sand (very fine) .	·00788
Sawdust . . .	·00736
Kamptulikon . .	·00660
Vulcanised India-rubber	·00534
Horn . . .	·00522
Beeswax . . .	·00522
Felt . . .	·00522
Vulcanite . .	·00500
Haircloth . .	·00241
Cotton wool (divided)	·00260
„ (pressed)	·00201
Flannel . . .	·00213
Coarse linen . .	·00179
Quartz, along axis .	·0553
„ „	·0745
„ „	·0340
„ „	·0498
„ Perpendicular	·240
„ „	·265

With regard to some of these substances, I may say that the white marble comes from Italy, though I know nothing more about it.

The slate is that commonly used for roofing.

The snow was frozen, and in consequence did not compress very evenly.

The cork was cut so that the conduction was along the fibre.

The pasteboard was the thick brown material often called millboard.

The carbon was kindly lent me by Professor Tait.

The roofing felt was that commonly known as asphalte roofing felt.

The firwood was thoroughly seasoned.

The boiler cement is that supplied by Messrs Fleming, 23 St Vincent Place, Glasgow, and was kindly given to me along with several other materials.

The paraffin is that kind which has its boiling point at 45° C.

The sand was very fine, nearly pure silica, being that used for sand-baths.

The sawdust was that of common firwood, and was compressed.

The flannel was of the very coarse kind usually known as washing cloth.

The coarse linen was of the coarsest possible texture.

The quartz used for conduction along the axis was very thin. The piece used for conduction perpendicular to the axis was a large piece in the form of a hexagonal prism.

With regard to the numbers, I must say, in the first place, that they differ considerably from those of Peclet in nearly all the cases that admit of comparison. Reducing his numbers to the units employed above, we find—

Substance.	Forbes.	Peclet.
White marble .	·0691	·463
Glass . . .	·0300	·125
Carbon . . .	·0243	·827
Caoutchouc . .	·00534	·028
Sawdust . .	·00735	·011
Cotton wool . .	·00530	·00666

It appears that there is a constant error due to the difference of methods. But it may be well to remark that Peclet has found very different results at different times, as may be seen at once by comparing the tables given at pages 355 and 481 of his "Traité de la Chaleur," 1843, vol. ii., and at page 406 of the second vol. of the same work as published in 1861. My experiments have at times varied, and I have given all the values I obtained for quartz, to show how injudicious it is to use a thin piece of a substance that is not a very bad conductor. The surface resistance is in that case too great to give good results. I intend to make further experiments on the conduction along the axis of quartz, which, along with a continuation of this investigation, I hope to have the honour of laying before the Society at a future time.

But these remarks do not apply to really bad conductors, and I have every reason to believe that the numbers given above do not differ widely from the truth.

The experiments on firwood confirm what we know about the difference in conduction along the different axes.

The experiments on cotton wool by no means refute what Peclet has found, viz., that the conduction is the same to whatever degree the wool is compressed, thus leading to the most interesting conclusion, that the conductivity of the fibre is the same as that of air, and that the conductivity of air is the number given above. The very low conductivity of many of these substances are proverbial; more especially flax, which we find at the bottom of the list. Horns and hoofs have also a bad name. The makers of boiler cement are well aware that they could have worse conductors, but they must consider the expense.

In all these experiments I was much assisted by Mr James Guthrie, one of my laboratory students.

3. On the Formation of Coal, and on the Changes produced in the Composition of the Strata by the Solvent Action of Water slowly percolating through the Earth's Crust during long periods of Geological Time. By R. W. Thomson, C.E., F.R.S.E.

(*Abstract.*)

The author commences by adverting to a very generally recognised geological difficulty—viz., that of accounting for the disappearance of the mineral from the carbonaceous matter in the processes which have resulted in the formation of coal-beds as we now find them. Coal-beds have undoubtedly their origin from decaying vegetable matter; and the deposition is unquestionably traceable to at least three different sources—viz., the carrying down by rivers of drift wood, and its deposition in deltas and estuaries at their mouths; the accumulations of dead forest trees, &c., falling for successive generations where they had grown; and the growth of peat. But in all of the three methods it is clear that the vegetable matter must have been mixed up to a very large extent with earthy matter, which earthy matter has since disappeared, so as to leave carbonaceous deposits in a comparative state of purity. The explanation of this disappearance has hitherto completely baffled geological ingenuity, and the author, in offering the present solution of the enigma, ventures to hope that he has successfully grappled with the difficulty. Geologists appear hitherto to have strangely overlooked, or at all events very much underrated, the solvent powers of water in effecting changes on strata during inconceivably long periods of geological time, at great depths, and consequently under greater pressures and higher temperatures than are obtainable at the surface of the earth. The author contends that a just comprehension of the solvent action of water, slowly percolating through the strata during vast and nameless periods of time, and at pressures and temperatures of unknown intensity, will furnish the key to the elimination of the mineral from the carbonaceous matter which now constitutes our beds of coal. If carbon be not actually insoluble, it may be assumed that it is practically so in relation to any known chemical action and as compared with the proportionately easy solubility of the mineral ingredients, for the extension of which the present explanation is offered. Granting, therefore, the vast difference in degree of solubility, the immensity of the time since deposition, and the increased pressure and temperatures, with the incessant percolation of water through the strata, it is impossible to conceive any other result than the gradual washing out of the soluble from the insoluble constituents of any particular stratum. The different ingredients would disappear in the rotation of their degrees of solubility; and, in the case of coal-beds, the separation and carrying away of the mineral or soluble ingredients in solution and the leaving the carbonaceous or insoluble matter behind, would seem to be simply a question of time. The author touches upon several collateral features connected with the solvent action of water percolating through the strata, such as the deposition of chemically-dissolved matter in other strata through which the water has to pass at a lessened temperature, and consequently with a diminished power of solution, the vast supplies of shell-forming substances constantly being carried into the sea, and thus maintaining a supply sufficient for the formation of myriads of shells, and whole islands and almost continents of coral reef; and, in conclusion, he submits that the solution now offered, besides doing away with the principal difficulty, will contribute to the elucidation of many other obscure points in geology.

4. Note on Homocheiral and Heterocheiral Similarity. By Sir William Thomson.

Monday, 3d March 1873.

The Hon. Lord NEAVES, Vice-President, in the Chair.

The following Communications were read:—

1. On the Mud Banks of Narrakal and Allippey, two Natural Harbours of Refuge on the Malabar Coast. By George Robertson, Esq., C.E.

In the course of an examination of the harbours and river mouths of India, which I have recently been making for the Government of that country, instructions were sent me to examine the backwater communication of the Malabar coast, with special reference to the possibility of taking advantage of the anchorage at such localities as Narrakal and Allippey, and opening out communications between them and the backwaters. As these anchorages are so remarkable, and the phenomena connected with them are probably known to but few members of this Society, and the places themselves perhaps never visited by any member present, I have thought a short account of these mud harbours of refuge would be of some interest.

And, first, for a few words on the backwaters of Malabar. These consist of a network of lakes, river mouths, short rivers, and artificial cuts or canals, by which cargo boats can travel, with but one or two interruptions (now being overcome), from Buddagherry (to the north of Calicut), in lat. 11°·35, to Trevandrum, the capital of the state of Travancore, in lat. 8°·29. Eventually the system will be continued almost to Cape Comorin. The great value of this internal water communication is best shown in the south-west monsoon, when communication by sea is suspended for several months.

The south-west monsoon, which commences early in June, is a great bugbear to the commerce of the west coast of India, partly because there are few harbours which can easily be entered in it, and ships lying out at sea could not communicate with the shore; and partly because the native craft are so ill found and such rattle-traps of vessels, that they would go to the bottom. But it is simply a long continuance of tolerably steady-blowing strong winds, with torrents of rain, such as we do not have in this country, and not the least formidable to properly-found vessels or to steamers. I have been at sea in the worst burst of the south-west monsoon, and never felt the slightest uneasiness, much less serious thought of danger.

The cyclones in the Bay of Bengal, on the east coast, are of course very different.

The rain, however, in the south-west monsoon is a serious drawback to shipping cargoes.

I explored about 200 miles of the internal water-communication, reporting on Calicut, Beypore, and Cochin harbours for the Government of India, and also on Quilon, at the request of the Maharajah of Travancore, and the Dewan, Sir Madava Row. The canals in the northern position have only 2 feet 6 inches of water as a minimum, but in the Travancore state they are all intended to have 4 feet. I advised that the latter depth should be extended to the full distance, and the canals in various places straitened, so that the whole system might be opened up for small steamers, both to carry passengers and to tow cargo boats.

The greater part of the distance that Col. Farewell, superintending engineer, South Canara, and I travelled, was through cocoanut groves, and we had cabined boats, with from twelve to twenty rowers each, who sang fearful choruses almost the whole way.

The scenery was very beautiful, especially near Quilon, but the heat often very great, and always stifling. Of course, when we had to sleep in the boat, the mosquitoes were very troublesome.

The backwaters run parallel to the coast, and at a short distance from it, at times swelling out into lakes of varying sizes, the largest being at Cochin, where the backwater is almost the size of Loch Lomond. There are many mouths into the sea; some being shut up during the dry weather by the bars of sand which the surf is constantly throwing across any opening in the coast line; others, like the entrance at Cochin, remaining open for navigation all the year round.

At Cochin there is always 11 feet of water at low water on the bar; but I hope that 20 feet will be attained by the works now projected, which will make Cochin by far the best harbour in the south of India.

The two mud banks I am going to describe are most valuable adjuncts to Cochin. Narrakal is about five miles to the north, and Allippey nearly forty miles to the south.

Allippey is the better known of the two, and I therefore take it first. In an old book (I believe on the voyages of Captain Cope) Allippey is mentioned in a way which proves that its peculiarities and advantages have been long known and appreciated. For this fact—and indeed for almost all I know of the mud bank—I am indebted to information obtained from Mr Crawford, the commercial agent for the state of Travancore, a shrewd Scotchman, who resides at the thriving and busy town of Allippey, and occupies a position of great responsibility. The bank is spoken of in that book as "Mud Bay," and described as one of the most extraordinary harbours in the world.

From Hamilton's account of the East Indies, in Pinkerton's collection of "Voyages and Travels" (1673 to 1723), it is thus spoken of, according to a report by Mr Maltby, the resident in 1860:—

"Mud Bay is a place that, I believe, few can parallel in the world. It lies on the shore of St Andrea, about half a league out in the sea, and is open to the wide ocean, and has neither island nor bank to break off the force of the billows, which come rolling with great violence on all other parts of the coast in the south-west monsoon, but on the bank of mud lose themselves in a moment; and ships lie on it as secure as in the best harbour, without motion or disturbance. It reaches about a mile along shore, and has shifted from the northward, in thirty years, about three miles."

There is some discrepancy in the statements of the movements of the bank in former times as to whether it moved from north to south or from south to north; but there can be no doubt about the last movement, since it has taken place during Mr Crawford's residence at Allippey.

In Lieutenant Taylor's chart of 1859, the bank is shown off the town of Allippey in lat. 9°·30. But, since then, it has moved four miles to the south, where it was when I examined the place, along with Mr Crawford, in March 1871. A letter from that gentleman in 1860 to the resident at Travancore gives the following account of this bank, with some of the theories which have been started in connection with its properties:—

"Lieutenant Taylor attributes the smoothness of the water to the soft mud at the bottom, by which, when 'stirred up by a heavy swell from seaward, the activity of the waves is so deadened as to render the shore-line free from surf.' I regret never having met Lieutenant Taylor.

"A number of years ago I brought to the notice of General Cullen, that the perfect smoothness of the water in the roads, and at the beach at Allippey, was attributable, not to the softness of the mud at the bottom so much as to the fact of the existence of a subterranean passage or stream, or a succession of them, which, communicating with some of the rivers inland and with the backwater, become more active after heavy rains, particularly at the commencement of the monsoon, than in the dry season, in carrying off the accumulating water, and with it vast quantities of soft mud. General Cullen, the resident, sent a quantity of piping and boring apparatus in order to test the existence, or otherwise, of what I had urged. Accordingly, I sunk pipes about 700 yards east from the beach, and at between 50 and 60 feet depth; and, after going through a crust of chocolate-coloured sandstone, or a conglomerate mixture of that and lignite, the shafting ran suddenly down to 80 feet; fortunately, it had been attached to a piece of chain, or it would have been lost altogether. Several buckets from this depth were brought up, which correspond in every respect with that thrown up by the bubbles as they burst at the beach, which I shall here attempt to describe as accurately as I can. Due west of the flagstaff, and for several miles south, but not north of that, the beach will, after or during these rains, suddenly subside, leaving a long tract of fissure, varying from 40 to 100 or 120 yards in length; the subsidence is not so quick at first; but, when the cone of mud once gets above the water, the fall is as much as 5 feet in some instances, when the cone bursts, throwing up immense quantities of soft soapy mud, and blue mud of considerable consistence, in the form of boulders, with fresh water, debris of vegetable matter, decayed, and in some instances green and fresh. These bubbles are not confined to the seaboard, but are, I am inclined to think, both more active and numerous in the bed of the roads with the flagstaff bearing from E.N.E. to the south, until it bears N.E. by N., or even south of that. About five years ago, for about four miles down the coast, and from the beach out to sea for a mile and a half, the sea was nothing but *liquid* mud, the fish died, and as these cones reared their heads above the surrounding mud, they would occasionally turn over a dead porpoise and numerous fish; the boatmen had considerable difficulty in urging their canoes through this to get outside of it; the beach and roads presented then a singular appearance; nothing to be seen but those miniature volcanoes, some silent, others active; perfect stillness of all around the ships in the roads, as if in some dock, with a heavy sea breaking in seven fathoms outside.

"There are numerous deep holes, some of them I measured in 1852; one in particular, just at the end of this canal, had as much as 60 feet in depth; these holes may, or may not, communicate directly with the roads, but I think it will be found that the principal source of active communication is more inland, and the backwater perhaps only an auxiliary. About three miles above Chenganoor, in the river of that name, there are one or two deep "Linns" which I only had an opportunity of visiting twice; the first time I had not the means of ascertaining the depth, the next I lost both lead and line.

"The depth of this passage is not so great as you approach the beach, as noticed above; for, while extending the canal from the Timber Depôt in March last, about 200 yards from the beach, at 12 feet we suddenly and unexpectedly broke through the substratum, when a column, fresh water, mud, and vegetable debris, and about nine inches in diameter, spouted up, which, when left alone, gradually subsided as the upper stratum of sand filled in round the column of the spring.

"I submit the above information, as I feel that it will be interesting, both to yourself and Government, to pursue the investigation of this subject more efficiently. I have omitted to state one important particular,—that is, should *no* rain fall, as has been the case this year, the sea in the roads and at the beach is not *nearly* so smooth; up to this time we have had none of the mud cones bursting at the beach, neither in the roads, as the waves tumble in perfectly clear; there was a heavy surf from the 26th ultimo to 9th instant, but never, in any instance, for these last eleven years, has the rain held off so long as in this, and the roads and beach have always, by the end of May, been perfectly smooth."

Since that letter was written, the bank has left Allippey, and has shifted some four miles down the coast, which considerably complicates the theories put forward. The oscillation of the bank —for it is said by some to have previously had a northward tendency—is very puzzling, viewed in connection with any supposed underground communication with the backwaters. The smoothness in rough weather is said to extend out to about the six fathom line. This is a point worth noticing, because, unless the mud suddenly stops there, it shows the extreme limit at which the waves on this coast have any effect on the bottom, even when that is composed of very fine slushy mud.

Mr Crawford states that the mud cones he describes take place only during the monsoon. At all events, I did not see any in action during my visit. He told me, likewise, that during the monsoon there is fresh water on the Allippey bank, but could not say whether it was succeeded by salt water to the north or south. This would require to be known, to make the existence of fresh water during the rains at all curious. It is possible that the fresh water may extend all the way to Cochin harbour entrance, and owe its existence either to that outlet on the north, or to some other outlet to the south.

Towards the formation of any theory about the Allippey bank, it will be useful to note that Mr Crawford has measured the level of the water in the backwater during the height of the monsoon, and found it to be 3 feet 2 inches above the sea-level. This gives a hydrostatic pressure from the backwater of less than a pound and a half on the square inch. The backwater is about two and a half miles from the sea at Allippey.

Mr Crawford, when I saw him, had an idea that volcanic action has something to do with the mud cones described by him, but was unable to overcome the difficulty I suggested, that it was only regularly at one time of the year, and that during the rainy and windy season, that the mud cones appeared.

There is a curious circumstance about the Allippey bank, which I give also on Mr Crawford's authority, viz., that, in gales of wind, vessels may be seen lying at anchor on the bank with their bows pointed in various directions, as if influenced by eddying currents in the sea of mud.

The weather being too calm, and the time of year being too early, to exhibit the full virtues of the bank, I noticed none of these wonders, but I saw enough to show that there was some extraordinary virtue in the place. We got into the boat with some difficulty at Allippey, on account of the surf; but, at the place where the bank now is, for several miles there was not only no surf, but not a ripple at the water's edge, and we stepped on to the shore from the boat with the greatest ease. Looking from shore towards the sea horizon, one saw a crest of surf, or, more properly speaking, swell, all round in a horse-shoe form, and reaching out to about three and a half miles from land, enclosing this smooth pond,—the swell being gradually deadened as it neared shore, till it died off into absolute quiescence.

I passed Allippey in a P. & O. steamer last autumn during the height of the S.W. monsoon; but, although within sight of land, we were too far off to notice the peculiarities of the mud bank.

The *Narrakal* bank, at present five miles to the north of Cochin, has been known for long, but was almost forgotten till it was rediscovered (I may say) by Captain Castor, the master-attendant at Cochin in 1861, and surveyed by him in 1865. Captain Castor (who is a native and a very intelligent man) is now master-attendant at Coconada, but was ordered to meet me at Cochin, so that I had the advantage of his presence in visiting Narrakal. Curiously enough, he is now stationed at the only place I visited in India, which approached in character to the peculiarities of these mud banks; for, at Coconada, there is a quantity of mud in the bay, which to a considerable extent reduces the surf. But Coconada is a regular bay, into which the Godavery river discharges its mud; whilst the banks now in question are detached spots of a peculiarly greasy mud, moving about on a straight coast, and away from any river mouth.

In some of the records of the late Captain Biden, the then master-attendant of Madras, is to be found the following remark about Narrakal (date 1841):—"This bank is situated at Pooryapooly about nine miles to the north of Cochin within the Cochin Circar's territories; the extent of it is about six miles, and the soundings from one to seven fathoms."

But there is a much earlier reference to Narrakal, in the translation of an old work by a Dutch navigator, called "Voyage to the Cape of Good Hope, Batavia, Samarang, Surat, East Indies, &c., in the year 1774 to 1778," book iii., cap. 12.

In describing Cochin, he says—"The coast is safe and clear everywhere along the Company's Establishment, except at the mouth of the river of Cranganore [about twelve miles to the north of Cochin]. South of the above-mentioned mouth of the river of Cranganore there is a bay formed of mud banks, the banks forming which extend to fully a league out to sea, and into which vessels may run with safety during the bad monsoon, and may lie in twenty and less feet of water, almost without anchors or cables, in perfect security against the heavy seas which then roll in upon this lee shore, as they break their force upon the soft mud banks, and within them nothing but a slight motion is perceived."

A better description of Narrakal could not be given than is given by this writer of a century ago, except that the action of the mud extends out to the six fathom line, and that the bank has shifted south to within five miles of Cochin.

I heard nothing about mud cones in connection with Narrakal;—either there were none, or there was no one to observe them.

I visited Narrakal in the pearl fishery steamer, the "Margaret Northcote," which had been lent to me for the cruise round Cape Comorin, and which drew only five feet of water, so that we were able to go through the Paumben Passage, and thus save the voyage round Ceylon. I may mention that this last autumn I visited Paumben again, to report on the proposed ship canal which will shorten the voyage from Europe and Bombay to the Bay of Bengal, by three and a half days on the double voyage. The day we visited Narrakal there was a considerable swell on, and its effects were very marked on the countenance of the Prime Minister of Cochin, who had ventured on the sea, probably for the first time. In return for the compliment, he turned out the state snake-boats of the Rajah to attend us next day. They are very long narrow-framed canoes, each with some fifty rowers, who sit with their legs dangling over each side of the boat alternately; and they go at a great pace. The "bucksheesh" for so many men came to be heavy!

I sent a diver down for a specimen of the mud (which I regret to have lost). It is of a peculiarly greasy nature, dark green in colour, and sticky; a specimen was analysed at Madras in 1861, and was found to contain—

1. Very minute angular fragments of quartz, the largest hardly visible without a lens; this is the sand
2. Foraminiferous shells of the genus Rotalia, and a few fragments of larger shells.
3. Upwards of twenty genera of Diatomaceæ.
4. A few specules of sponges and corals, very minute.
5. Some amorphous matter, which was not destroyed after long boiling in strong acids.

I reported to the Government against attempting to open out communication between either of the mud banks and the adjoining backwater. A cut through the neck of land between would throw an outwards scour during ebb tides, and during the rains into the centre of the mud banks, and might do a great deal of harm, and indeed destroy them, or shift their position. During the dry season, at flood tide the mud would be drawn into the backwaters, and choke them up.

If a lock were to be put on the canal, the channel leading to it could not be kept clean without a scour.

At Narrakal there is already a canal from the backwater to within a few yards of the shore; and at Allippey there is a similar one, only the mud bank has left it and travelled south.

These natural harbours of refuge are too valuable to try experiments on; and I think the whole phenomena connected with them are *well worthy of careful scientific investigation.*

2. The Meteorology of the Month of May. By Alexander Buchan, M.A.

Excepting the months of January and July—the months of extreme temperatures for the larger portions of the globe—there is no month the meteorology of which is so peculiar, and a careful investigation of which is so likely to lead to striking and important results, as the month of May. The peculiarity of the meteorology of the month of May is, that it is the month of the year during which the most rapid rise of temperature takes place over the greater parter part of the northern hemisphere, and the most rapid fall over the greater part of the southern hemisphere; and since that rapid rise and equally rapid fall takes place at very different rates, according to the peculiar distribution of land and water in each region, the inquiry is calculated to bring out in strong relief some of the more prominent causes which influence climate, and some of the more striking results of those causes. The method of inquiry which has been adopted was to compare the average atmospheric pressure of May with that for the year, setting the difference of excess or deficiency in their proper places on maps, and drawing therefrom lines of equal deviation from the annual mean, for every 0·100 inch, and in some cases for 0·050 inch. The winds had been dealt with in a similar way—viz., by finding the difference between the average of May and the general monthly averages of the year. From these two elements—distribution of pressure and winds—the rainfall and other elements of climate necessarily follow. The results of the inquiry which has been made, and which was based upon observations at upwards of 600 places, show a diminution of pressure in May over tropical and sub-tropical regions, and also over the north of Asia and to the south of South America and Tasmania. The excess of pressure in the northern hemisphere prevails over North America (to the north of the Lakes), over Arctic America, over Greenland, over the British Isles, and to the north of a line passing through the English Channel, in a north-easterly direction, to the Arctic Sea. Excess in the southern hemisphere includes the southern half of South America and of Africa, the whole of Australia, and the adjacent parts of the ocean. The influence of land in the southern hemisphere, where the land at this season is colder than the surrounding sea, brings about a higher pressure for May; but the influence of land over regions heated more immediately by the sun brings about a lower pressure—interesting examples of which are seen in the distribution of the differences of pressure over India, the Malayan Archipelago, the Mediterranean, Black, and Caspian Seas. In many such cases the lines follow more or less closely the contour of the coasts, or, more strictly speaking, the lines resembling the contours lay some distance to eastwards, so that there is a less diminution over those seas than over the land surrounding them. Nearly the whole of Asia shows a very large deficiency of pressure—the Arctic regions to the north of Europe and North America the maximum excess of pressure. It is to the position of Great Britain, with reference to the deficiency of pressure on the one hand, and the excess on the other, that the east winds at this time of the year are due. Those easterly winds prevail over the whole of northern Europe, as far south as a line drawn from Madrid in a north-easterly direction, and passing through Geneva, Munich, &c. To the south of that line the diminution of pressure is less, and over that region the excess of wind is, not easterly, but southerly. Crossing the Mediterranean, and advancing on Africa, we approach another region of lower pressure; and towards that region north-easterly winds again prevail, as at Malta, Algeria, &c. The effect of these different winds upon the rainfall is very decided. Southerly winds from the Mediterranean result in heavy rainfall over France and Central Europe in the month of May.

The effect of those east winds upon diseases is very great. They derange our nervous system, and bring about a series of complaints, physical and mental, an inquiry into which would form an interesting and important subject of investigation.

3. On Vortex Motion. By Sir William Thomson.

The following Gentlemen were elected Fellows of the Society:—

Andrew Pritchard, M.R.I., Author of a work on Infusoria, Highbury, London.

Walter Stewart, F.C.S., Haymarket Terrace.
Robert Tennent, Esq., 21 Lynedoch Place.
Robert Walker, M.A., Edinburgh Academy, Fellow of Clare College, Cambridge.
William Boyd, M.A., Peterhead.
Morrison Watson, M.D., Demonstrator of Anatomy in the University, Edinburgh.
J. Bell Pettigrew, M.D., F.R.S., Conservator of Museum, Royal College of Surgeons.

Monday, 17*th March* 1873.

SIR ALEXANDER GRANT, Bart., Vice-President, in the Chair.

The following Communications were read:—

1. A Contribution to the Visceral Anatomy of the Greenland Shark (*Lœmargus borealis*). By Professor Turner.

Naturalists have recorded a few instances of the capture of the Greenland shark in the British seas. Dr Fleming states that one was caught in 1803 in the Pentland Firth, and that one was found dead at Burra Firth, Unst, in 1824. Mr Yarrell refers to a specimen caught on the coast of Durham in 1840, which has been preserved in the Durham University Museum. In May 1859, a specimen about ten feet long was caught in the Firth of Forth, near Inchkeith, the stuffed skin of which is preserved in the Edinburgh Museum of Science and Art. In 1862 a specimen was caught on the Dogger Bank, and brought into Leith. A brief description of its external character was read by Mr W. S. Young to the Royal Physical Society of Edinburgh. On April 27, 1870, Dr John Alexander Smith read before the same Society a notice of a female specimen caught about thirty miles east of the Bell Rock. It had become entangled in one of the deep-sea fishing-lines, many of the hooks attached to which had stuck into its body. It measured about 15 feet in length, and 3 feet 1 inch between the tips of the tail-lobes. The stuffed skin of this fish is also preserved in the Edinburgh Museum of Science and Art. In the month of February of the present year, three specimens were caught by fishermen at sea, some miles east of the Bell Rock, and brought into Broughty

Ferry. One was taken to Dundee for exhibition; the others were brought to Edinburgh for the same purpose. By permission of the proprietors, the author was enabled to examine the latter specimens, and to acquire for the Anatomical Museum the viscera and other parts. One was a large female, 11 feet 8 inches in length; the other, a smaller female, 8½ feet long. Colour, bluish-grey; sides of body marked with a number of transverse stripes; lateral line distinct. The author then recorded several measurements of the larger specimen, of which the more important were as follows:—

	Ft.	in.
From tip of snout to end of tail, . .	11	8
,, to back of 1st dorsal fin, .	6	0
,, to back of 2d dorsal fin, .	9	0
,, to antr. edge of ventral fin,	7	9
,, to antr. edge of pectoral fin,	3	5
Height of 1st dorsal fin, ...	0	7
,, 2d dorsal fin, ...	0	5¼
Between tips of tail-lobes, . . .	2	9
Length of pectoral fin, ...	1	8
,, ventral fin, ...	1	3

A specimen of the parasitic crustacean, the *Lerneopoda elongata*, was attached to one of the eyes of the smaller specimen.

The author then gave an account of the visceral anatomy of this shark; all the measurements given being from parts of the larger specimen. The stomach possessed, in addition to the large sac, a posterior pyloric compartment from which the pyloric tube arose, which curving for 6 inches forwards, terminated by a very constricted orifice in the duodenum.

The duodenum was a cylindrical tube, 3 feet 2 inches in length. It ran at first forwards and then passed backwards to end in a dilated part of the intestine 13 inches long, which contained the transversely arranged spiral valve. A short rectum, 7 inches long, passed from the spiral valve back to the anus, and into this part of the gut the duct of an ovoid glandular body, attached to the outer coat of the rectum, opened. The biliary and pancreatic ducts pierced independently the wall of the duodenum, where it bent on itself, and between their opening and the pyloric orifice two large cæca, one 6 inches, the other 18½ inches long, opened by wide mouths into the duodenum.

The pancreas was a well-developed organ, from which two long processes passed backward parallel to the duodenum. The bile-duct, for some inches before it joined the duodenum, was a single, well-marked tube, and had connected with it a small bilobed body, from which a minute duct, parallel to the bile duct, ran towards the liver. The spleen was 17 inches long and 6 wide at its broadest part. The kidneys lay parallel to the spine; their ureters, about the size of crow quills, opened into the cloaca behind the anus.

The ovaries were two in number, and each was 23 inches long in the larger shark. They consisted of parallel club-shaped laminæ, and contained multitudes of ova, varying in size from minute specks to small bullets. No oviducts were seen in the abdominal cavity, and no oviducal openings in the region of the cloaca; but immediately posterior to the mouth of the cloaca, the two rounded openings of the abdominal pores, which communicated with funnel-shaped prolongations of the peritoneal cavity were found.

The heart, with its subdivisions into auricle, ventricle, and conus arteriosus, was then described, and the structural differences between the conus and the bulbus aortæ of the osseous fish were pointed out.

The conus arteriosus of the heart, in addition to the large three-segmented, semi-lunar valve at its anterior end, contained four tiers of valves, consisting of nineteen cuspidate segments, to and from which, and from the inner wall of the conus, chordæ tendineæ proceeded.

It was then pointed out that the presence of a pyloric compartment, and of a cylindrical tubular duodenum, the co-existence of a pancreas and pyloric cæca, and the absence of oviducts, constituted most important features of difference between the Greenland shark and the other Plagiostomata.

Attention was then drawn to the differences in the form of the teeth, which had led Müller and Henle to separate the Greenland shark from the old Cuvierian genus *Scymnus*, and to make for it a new genus *Læmargus*.

The author then stated that the anatomical differences between

Scymnus and *Læmargus* were very much greater than those referable to the form of the teeth, on which systematic zoologists had hitherto relied in their classification. These differences, indeed, affected not only the relations of *Læmargus* to *Scymnus*, but to the sharks generally, and called for a reconsideration on the part of the zoologist of the place which the Greenland shark ought to occupy amongst the Plagiostomata, and required the establishment of a separate family for the reception of the genus *Læmargus*, which family would possess the following characters:—

LÆMARGIDÆ.

No nictitating membrane; two dorsal fins; no anal fin; duodenum cylindrical; both a pancreas and duodenal cæca; in the female no oviducts.

Læmargus.—Dorsal fins short, the second not quite so high as the first; lower teeth oblique, truncate.

2. Additional Note on the Strain-Function, &c. By Professor Tait.

The author gave an account of the mode in which he had treated the Strain-Function in an elementary Treatise on Quaternions, soon to be published, mainly from the pen of Professor Kelland.

The coefficients of the cubic in φ are determined easily from the condition that homogeneous strain alters the volume of every part of a body in the same ratio.

A careful examination is bestowed upon the case of three real roots of the cubic; especially with regard to the distinction between the results of a self-conjugate strain and a rotational one.

The separation of the pure and rotational parts of a strain is very fully treated; and as special examples, the strain of a rigid body and a simple shear are analysed.

Finally, the following problems are solved:—

Find the conditions which must be satisfied by the simple shear, which is capable of reducing a given strain to a pure strain.

Find the relation between two linear and vector functions whose successive application produces rotation merely.

All this is independent of the differential calculus, but as the following results regarding the stress-function require its aid, the cannot be introduced into the work referred to. They will appear, with extensions, in the second edition (now printing) of the author's Treatise on *Quaternions*.

At any point of a strained body, let λ be the vector stress per unit of area perpendicular to i, μ, and ν, the same for planes perpendicular to j and k respectively.

Then, by considering an indefinitely small tetrahedron, we have for the stress per unit of area perpendicular to a unit vector ω, the expression

$$\lambda S i\omega + \mu S j\omega + \nu S k\omega = -\phi\omega,$$

so that the stress across any plane is represented by *a linear and vector function* of the unit normal to the plane.

But if we consider the equilibrium, as regards rotation, of an infinitely small rectangular parallelepiped whose edges are parallel to i, j, k, respectively, we have

$$V(i\lambda + j\mu + k\nu) = 0,$$

or

$$\Sigma V i\phi i = 0,$$

or

$$V.\nabla\phi\rho = 0.$$

This shows that ϕ is *self-conjugate*, or, in other words, involves not nine distinct constants but only six.

Consider next the equilibrium, as regards translation, of any portion of the solid filling a simply-connected closed space. Let u be the potential of the external forces. Then the condition is obviously

$$\iint \phi(U\nu)ds + \iiint d\varsigma\nabla u = 0,$$

where ν is the normal vector of the element of surface ds.

Here the double integral extends over the whole boundary of the closed space, and the triple integral throughout the whole interior.

To reduce this to a form to which the method of my paper on *Green's and other Allied Theorems* (*Trans.* R.S.E., 1869-70) is directly applicable, operate by $S.\alpha$ where α is any constant vector whatever, and we have

$$\iint S.\phi\alpha U\nu ds + \iiint d\varsigma S\alpha\nabla u = 0,$$

by taking advantage of the self-conjugateness of ϕ. This may be written

$$\iiint d\varsigma(S.\nabla\phi\alpha + S.\alpha\nabla u) = 0\,,$$

and, as the limits of integration may be any whatever,

$$S.\nabla\phi\alpha + S.\alpha\nabla u = 0 \quad . \quad . \quad . \quad . \qquad (1).$$

This is the required equation, the indeterminateness of α rendering it equivalent to *three* scalar conditions.

As a verification, it may be well to show that from this equation we can get the condition of equilibrium, as regards *rotation*, of a simply connected portion of the body, which can be written by inspection, as

$$\iint V.\rho\phi(U\nu)ds + \iiint V.\rho\nabla u d\varsigma = 0\,.$$

This is easily done as follows:—(1.) Gives

$$S.\nabla\phi\sigma + S.\sigma\nabla u = 0,$$

if, and only if, σ satisfy the condition,

$$S.\phi(\nabla)\sigma = 0\,.$$

Now this condition is satisfied if

$$\sigma = V\alpha\rho\,,$$

where α is any constant vector. For

$$\begin{aligned} S.\phi(\nabla)V\alpha\rho &= -S.\alpha V\phi(\nabla)\rho \\ &= S.\alpha V\nabla\phi\rho = 0\,. \end{aligned}$$

Hence

$$\iiint d\varsigma(S.\nabla\phi V\alpha\rho + S.\alpha\rho\nabla u) = 0\,,$$

or

$$\iint ds S.\alpha\rho\phi U\nu + \iiint d\varsigma S.\alpha\rho\nabla u = 0\,.$$

Multiplying by α, and adding the results obtained by making α in succession each of three rectangular vectors, we obtain the required equation.

Suppose σ to be the displacement of a point originally at ρ, then the work done by the stress on any simply connected portion of the solid is obviously

$$W = \iint S.\phi(U\nu)\sigma ds\,,$$

because $\phi(U\nu)$ is the vector force overcome on the element ds.

This is easily transformed to

$$W = \iiint S.\nabla\phi\sigma d\varsigma\,.$$

Monday, 7th April 1873.

Professor Sir WILLIAM THOMSON, Vice-President, in the Chair.

The following Communications were read:—

1. Notice of a Singular Property exhibited by the Fluid enclosed in Crystal Cavities. By Edward Sang, Esq.

The subject of the following communication is a phenomenon unexpected and peculiar; it presents analogies to the phenomena of magnetism and electricity, in so much as it is an exhibition of repulsion; but it is distinguished from these by the absence of attraction, or what is called polarity. So far as I am aware, it is the only known example of repulsion exhibited independently of magnetic or electric excitement, and seems to open up an entirely new field for physical research. On these accounts I was exceedingly desirous to have it brought without delay to the notice of scientific men, and I have to thank our Secretary for giving me the present opportunity, although at the inconvenience to him of it having to accompany a long and interesting paper on another subject.

I shall confine myself this evening to a simple statement of the nature of the phenomenon, to its exhibition, and to an account of the circumstances that led to its discovery, reserving for another opportunity a more detailed notice of those observations and experiments that have already been made in regard to it.

While discussing, along with Dr James Hunter, the occurrence of polished cylindric striæ in calcareous spar, and while examining those striæ under the microscope, I happened to notice an air-bubble in a minute cavity, having a regularly crystallised form, which air-bubble was found to move when the position of the spar was changed.

Next forenoon, while showing this, in itself very interesting, matter to my pupil, Mr David A. Davidson, I desired to mark the position of the speck, and applied the point of my penknife to scratch the spar. Immediately the air-bubble was seen to move rapidly. My first thought was to attribute this motion to the pressure on the thin lamina of spar immediately above the cavity, but on exerting a much greater pressure by help of a small pencil of wood, no motion was perceptible, yet on bringing the knife-point within the field of view, but without pressure, the motion was renewed, and the bubble was seen to approach the steel on whichever side it might be placed. The possible slight magnetism of the steel suggested itself as an explanation, accompanied, however, by the unheard-of occurrence of a magnetised fluid; and the blade was magnetised first in the one and then in the opposite way without any perceptible change of effect. Meanwhile Mr Davidson had found that a piece of soft steel occasioned the same motions. Pieces of brass and copper wire, printing type, silver and copper coin, all acted in the same way; but pieces of wood, glass, ivory, showed no effect.

Afterwards, trials made with compact oxide of iron, and with sulphuret of lead, gave no perceptible result; yet, until the trials shall have been conducted with scrupulous care as to the horizontality of the upper surface of the cavity, we cannot hold the absence of action to be proved; but, as present appearances go, it seems that the metallic state is essential to this repulsion.

By inclining the instrument, we may bring this repulsion to oppose gravity, and the degree of inclination affords a test of the amount, so much so that means for determining the law of its variation by distance, and the specific influences of different metals, are brought within reach.

Modifications in the arrangement of the microscope, so as to allow of the convenient exposition of specific masses, as well as to secure the measurements of the inclination and distance, are needed before we can obtain results reliable as to quantity; when these modifications are completed I shall place the details before the Society.

Roughly made, as at present, the experiments point to a specific intensity for each metal, and to a diminution in a ratio higher than that of the inverse squares of the distances.

I have not been so fortunate as to find among the cavities in rock crystal, topaz, and amethyst, within my reach, any containing movable fluid: it is desirable that physicists, who may be in possession of such specimens, should examine whether this repulsion occur there also.

2. On the Germ Theory of Putrefaction and other Fermentative Changes. By Professor Lister.

The following Gentlemen were elected Fellows of the Society :—

John G. M'Kendrick, M.D., Assistant to the Professor of Physiology in the University of Edinburgh.
Robert Wilson, Esq., Engineer, Patricroft, Manchester.

Monday, 21*st April* 1873.

Professor KELLAND in the Chair.

The following Communications were read:—

1. Notice of New Fishes from West Africa :—
(I.) *Ophiocephalus obscurus*, Günther.
(II.) *Synodontis Robbianus*, nov. spec. mihi.
By John Alexander Smith, M.D.

The fishes now exhibited were brought by the Rev. Alexander Robb, D.D., from Old Calabar, West Africa. They were taken in the fresh water of the great Old Calabar River, near Ikorofiong, about a hundred miles or so, by the windings of the river, from the bar near its mouth. The Rev. Dr Robb resides at Ikorofiong, which is one of the stations of the Calabar mission of the United Presbyterian Church.

The fishes belong to the great sub-class of the TELEOSTEI.

I. *Ophiocephalus obscurus*, Günther.

The first to which I would call attention is a small dark-coloured fish; it belongs to the Order of the Acanthopterygii, Family Ophiocephalidæ, and to the Genus *Ophiocephalus.*

Dr Günther, in his "Catalogue of Acanthopterygian Fishes," vol. iii. p. 468, states that the fishes of this family have the *body elongate, anteriorly sub-cylindrical*, and covered with scales of moderate size; the head depressed and snake-like, covered with shield-like scales superiorly. *A cavity accessory to the gill cavity, for the purpose of retaining water in it*, a superbranchial organ, not being developed. *One long dorsal and anal fin without spines.* "They are fresh-water fishes of the East Indies, and are able to live and move without the water for a short time, feeding on small animals." "It appears, from recent observations, that the amount of air which is in solution in water is not sufficient for the respiration of these fishes, so that they are obliged to come to the surface at certain intervals, to receive an additional quantity of atmospheric air."

The genus *Ophiocephalus* is distinguished by the presence of ventral fins. The species of this genus are common in India and the East; some of them, as the "*Cora mota*" or "*Gachua*" (the *O. gachua*) of Bengal, have excited considerable interest from making their appearance during the rains in unexpected places, and giving rise to the popular belief that they must have fallen with the rain from the clouds; the fish having left, for the time, the muddy waters where it resides, for the fresh wet grass, and the abundance of animal food it gets there.

This genus was believed to be entirely confined to India and the East until Dr Günther, in the year 1869, detected in the collection of fish made by Consul Petherick on the Nile one species which he has described as the *O. obscurus.* It was captured at Gondokoro on the Upper Nile, and forms the only exception yet known to the Indian habitat of the genus.

The interesting fact of the great apparent correspondence of the fish fauna of the Nile with the distant rivers of West Africa was pointed out many years ago; the fauna of the East African rivers being apparently somewhat different in character. Dr Günther, from a careful examination of a number of species from the Nile and West African rivers, comes to the conclusion that—"the Faunæ of the Nile and the West African rivers belong to the same zoological district; that there is an uninterrupted continuity of the fish fauna from west to east; and that the species known to be common to both extremities inhabit also the great reservoirs of water in the centre of the African continent."*

It is, therefore, with some little interest that I am able to add this single species of *Ophiocephalus* found in the Upper Nile, to the list of corresponding species found in the great Calabar river of Western Africa. The specimen seems to correspond very closely with Dr Günther's typical description of the *O. obscurus*, with the exception of some slight proportional details of measurements and the presence of one or two more rays in some of the fins. I forwarded the fish to Dr Günther for his examination, and he writes me that "the *Ophiocephalus* is closely allied to, if not identical with, the *obscurus*, but it has five or six more dorsal rays than the type." We must, therefore, perhaps, wait for the examination of additional specimens, to see whether some of the characters will require to be expanded a little, in Dr Günther's description of the fish.

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* See Petherick's "Travels in Central Africa," vol. ii. London, 1869. Appendix, "Fishes of the Nile," by Dr A. Günther.

(Since this paper was read to the Society, Dr Günther informs me that the British Museum has recently received a specimen from the river Congo, with thirty anal rays.)

I subjoin Dr Günther's description of the Nile fish, taken from the appendix to Petherick's "Travels in Central Africa," vol. ii. London, 1869, p. 215. Dr Günther had, however, previously described and named this fish in his general "Catalogue of Acanthopterygian Fishes," vol. iii., London, 1861, p. 478, from a specimen in the collection of the British Museum, the locality of which was not known :—

"*Ophiocephalus obscurus*, A. Günther.

D. 42. A. 26–29. (L. lat. 70. L. trans. 7/14.)

"The height of the body is nearly one-eighth of the total length, the length of the head nearly one-fourth; the width of the inter-orbital space is more than the extent of the snout, and one-fourth of the length of the head. The cleft of the mouth is wide, the maxillary extending behind the orbit. The scales on the upper surface of the head are of moderate size, those on the neck small; there are thirteen series of scales between the orbit and the angle of the preoperulum. The pectoral does not extend on to the origin of the anal, and its length is one-half that of the head; the length of the ventral is three quarters of that of the pectoral. Caudal rounded, its length being six times and one-third in the total. Blackish, lighter below, with dark stripes along the series of scales; a series of black blotches along the side; head with two indistinct oblique black spots along its base. Pectoral and ventral variegated with blackish. Chin black, with white spots. Length seventy-seven lines. Collected at Gondokoro."

The following are some of the slight differences in the specimen got in the Old Calabar River :—

Ophiocephalus obscurus, A. Günther.

D. 45. A. 32. P. 16. V. 6. (L. lat. about 70. L. trans. 7/14.)

Height of body, 7½ times in total length of fish. Length of head, 4½ times in total. The length of the pectoral fin is a little more (⅛ of an inch), than half the length of head. Length of ventrals rather more than half that of pectorals. Caudal fin is 5¼ times in the total length. Head and body above are black, or a very dark brown (in spirits), the sides show numerous black blotches; fins black, tail slightly mottled with lighter. Below, head black, blotched with lighter, rest of body dirty white. Total length, 78 lines (6½ inches.)

Collected at Ikorofiong, Old Calabar River, West Africa.

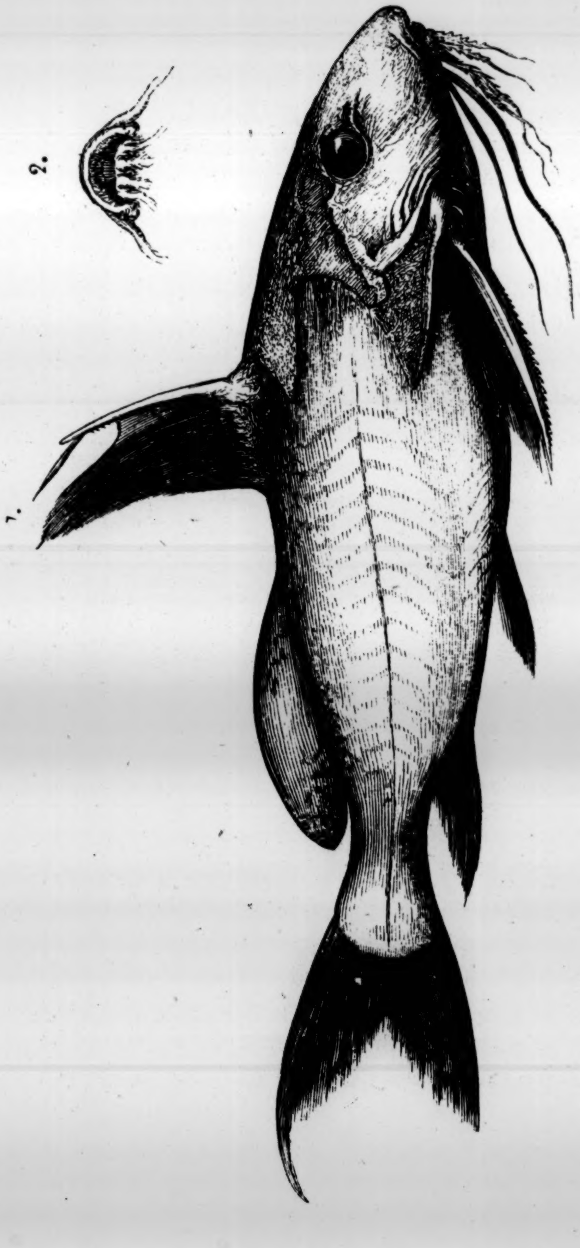
II. *Synodontis Robbianus*, nov. spec. mihi.

The other fish belongs to the Order of the Physostomi, Family Siluridæ, and to the Genus *Synodontis*. All the species of this genus belong to tropical Africa, and at least one species has been discovered common to the Upper Nile and the West African rivers. They are scaleless fish, with an adipose fin, and the dorsal and pectoral fins have strong bony spines. Mouth small, Teeth in the lower jaw movable, very thin at the base, and with slightly dilated brown pointed apices. They have six barbels, and broad dermal bones on the head and neck. I have taken these details of the characters of the genus from Dr Günther's important work, the "Catalogue of Fishes," vol. v., to give a general idea of the fish, and the following are the character of this new species:—

Synodontis Robbianus.

Body.—Height (behind dorsal fin), about one-fourth of length without caudal rays. Greatest height; one-third of distance between posterior border of orbit, and caudal extremity without fin rays. *Head* about three and a half times in length of body, without caudal fin; tapers quickly forwards; short in front of eyes; distance from point of snout to front of orbit, about one-third of length from snout, to posterior extremity of nuchal plate. Snout short, rounded in front; distance between middle of orbits rather less than to front of snout. The gill openings extend downwards to before the root of humeral process of pectoral fin.

Teeth:—Mandibular, rather numerous, much shorter than the eye (about half), varying in length, the longest towards the middle; in a cluster on



J. M. Corner, *Delt.*

1. *Synodontis Robbianus* (natural size).
2. Mouth, showing teeth and roots of barbels.

the middle of front of lower jaw. *Maxillary* teeth in front of upper jaw, small, short, thickly set in a broad band.

Barbels:—Maxillary barbels, dark-coloured, much longer than head, reaching more than half way down pectoral spines; edged with a broadish membrane interiorly. *Mandibular barbels.—Outer,* dark-coloured, slightly fimbriated or fringed, reaching to base of pectoral fin. *Inner*, light-coloured, about half the length of outer, and more distinctly fringed.

Dermal bones of head and neck.—Broad, rough or granular; terminate in front of eyes in forked processes; broad behind, and extend in a pointed process a little beyond each side of base of dorsal spine. *Humeral process.*—Much longer than high, pointed behind, runs nearly as far back as nuchal plate, granular surface, a slight projecting ridge along anterior margin, and a thick, somewhat smooth, and tapering ridge projects along its inferior border.

Fins rather small:—D. 1/8. A. 12. P. 1/7. (V. 7.)

Dorsal fin.—Spine shorter than the head (fixed upright), almost smooth in front, showing only some very obscure indications of a few short processes or teeth at upper part; toothed at upper part behind, teeth directed somewhat towards base of spine; (a small soft ray or filament inserted a little below the point.) First five rays (the third the longest) as long as spine and filament together. *Adipose fin.*—Elevated; longer than head; space between it and dorsal, about equal to length of base of dorsal fin without spine. *Pectoral fin.*—Spine larger and longer than dorsal, toothed on both sides; teeth small and thickly set together on outside, directed towards extremity of spine; teeth larger and more apart on inner side, and point towards base of spine; fin reaches a little beyond base of dorsal fin, but not to base of ventral fins. *Ventral fins.*—Small; in length pass anal opening, but do not reach to base of anal fin. *Anal fin.*—Larger than ventral.

Tail.—Forked nearly half the depth of rays; two uppermost rays produced about a third beyond others.

Colour (in spirits).—Pale brown, slightly blotched or mottled with darker, especially on head, at insertions of fins and tail, and on rays of fins and tail. Ventrals and anal fin nearly black. Spines light coloured.

Total length of fish without caudal rays, $4\frac{3}{8}$ inches; to extremity of elongated caudal rays, $5\frac{5}{8}$ inches. From point of snout to posterior extremity of nuchal plate ($1\frac{7}{8}$ inches), fully a third of total length to extremity of elongated caudal rays. Total length of specimen, $5\frac{5}{8}$ inches.

Captured at Ikorofiong, Old Calabar River, West Coast of Africa.

I have named the fish after the Rev. Alexander Robb, D.D., to whom I am indebted for these specimens, as well as various others, from the Old Calabar district of tropical Africa.

Dr Robb tells me there are great difficulties in the way of getting specimens of natural history of almost any kind in Old Calabar; and one in particular depends on the fact, that the natives eat at once all they can capture, and are most unwilling to give them up for any other than their own gastronomic purposes.

The fishes of this genus *Synodontis*, and the allied genera, are interesting to the geologist from their possessing dermal bony plates, and also these strong bony fin-spines, which are analogous in character to some of those in the fossil fishes, and to the *ichthyodorulites*, or fin spines, which are found fossil in many of our older rocks.

These bony spines are useful to the fish as weapons both of offence and defence, and require a very careful handling of some of the species, which grow to a considerable size, as they sometimes inflict serious wounds, which are said to be poisonous, even in some cases causing death. Dr Robb says, the dangerous character of the fish of this genus is well known to the Old Calabar natives, as well as, doubtless, to some of the animals which prey upon fish. Crocodiles are abundant in the river, and in some instances make a seizure of one of these fishes with the large bony spines, and cases have occurred of a crocodile being found dead with the spiny fish sticking in its mouth or throat. This circumstance has probably given rise to an Efik proverb well known among the people, to this effect,—"When the Crocodile is lucky, he catches *Inanga*" (the spineless cat fish); "when unlucky, he catches *Mkpi-kuk-i-kuk*" (the native name for this spiny fish or *synodontis*), the etymology of which, Dr Robb tells me, is not very obvious. The proverb, indeed, wonderfully resembles our own common saying about "catching a Tartar," and is frequently used by them in its more general application, as among ourselves.

2. The Electrical Conductivity of certain Saline Solutions, with a note on their Density. By J. A. Ewing and J. G. MacGregor, B.A. Communicated by Professor Tait.

(*Abstract*).

In the note on the density of the solutions prepared for the purpose of determining their electrical conductivity, it is shown that the ratio of the weight of salt dissolved in unit weight of water to the excess of the density of the solution thus formed over that of water (unity), is not constant, but increases, with greater or less rapidity, from the more dilute to the more dense. The work of previous experimenters on the electrical resistance of liquids is then reviewed at some length. Their chief difficulty has always been the electrolytic polarisation of electrodes.

The solutions under investigation were put in a glass tube, which was narrow along the central part, but widened at the ends for the reception of platinum electrodes; and by means of connecting wires it was made to form one of the arms of a Wheatstone's Bridge. High resistances were introduced into the other arms. The bridge was so arranged that the effect on the galvanometer could be observed the instant the battery circuit was closed, when for an indefinitely short period there is no polarisation. By successive passages of electricity, which were alternately in opposite directions, and between which the tube was short-circuited, opportunity was obtained of adjusting the resistances in the arms of the bridge, so that at last there was no deflection of the galvanometer needle due to the passage of the current. All measurements and observations were made at a temperature of 10° C.

Nineteen solutions of zinc sulphate were examined. The resistances of very dilute ones are very great, but fall off rapidly as the density increases, until it reaches about 1·08, after which they decrease much more slowly. At the density 1·2891, the specific resistance (*i.e.*, the resistance between opposite faces of a cube, whose side is 1 cm.) is 28·3 B.A. units. The resistances of solutions from this density to that of saturation increase, that of the saturated solution being 33·7 B.A.U. That solution, therefore, whose density is 1·2891, is the solution of maximum conductivity. By taking as ordinates the excess of the density of the various solutions over unity, and as abscissæ their specific resistances, the relation between density and resistance is shown graphically. The curve thus obtained is symmetrical, about an axis passing through the point of maximum conductivity, and the part of it which lies between the origin and that point is an hyperbola whose asymptotes are inclined at an angle less than a right angle.

Eleven solutions of copper sulphate were prepared and their resistances found. The spec. res. of the saturated solution is 29·3 B.A.U. The solution of maximum density is that also of maximum conductivity. The curve (described as above) is an hyperbola whose asymptotes are inclined at an angle less than a right angle.

Nine solutions of potassium bichromate, and nine also of potassium sulphate, were investigated. The resistances in both decrease up to the point of saturation, the least being, in the former, 29·6 B.A.U., and in the latter, 16·6 B.A.U. The curves are both hyperbolas; that of the bichromate has its asymptotes approximately perpendicular to one another, and that of the sulphate has them inclined at an angle greater than a right angle.*

Fifteen mixtures of equal volumes of solutions of copper and zinc sulphates were also examined. In all cases, the resistance of the mixture is less than the mean of the resistances of its components. The lowest spec. res. of any of the mixtures prepared, is 27·3 B.A.U., and it consisted of equal volumes of the two saturated solutions. The zinc sulphate appears to exercise the greater influence in the determination of the spec. res. of the mixtures.

3. On the Effect of Heating one Pole of a Magnet, the other being kept at a Constant Temperature. By D. H. Marshall, Esq., M.A., and C. G. Knott, Esq. Communicated by Professor Tait.

The following are a modification of some experiments conducted in the summer of 1871, and communicated to the Society on the 15th of January 1872. These consisted in heating a magnet uniformly throughout, and then noting the change in magnetic strength. Those conducted this winter consisted in heating one pole of a magnet, while the other was kept at a temperature as nearly constant as possible, and then noting the change of magnetic strength in both poles. The arrangement adopted was the same in both series of experiments, only being double in the latter. It consisted in having a magnet set magnetically east and west, each end of which passed through a cork fitted into a hole made in the side of a copper pot, one of which was filled with oil and heated by means of a brass Bunsen, while the other was filled with water at the temperature of the air of the room. The temperatures of both ends of the magnet could thus be ascertained by means of mercurial thermometers.

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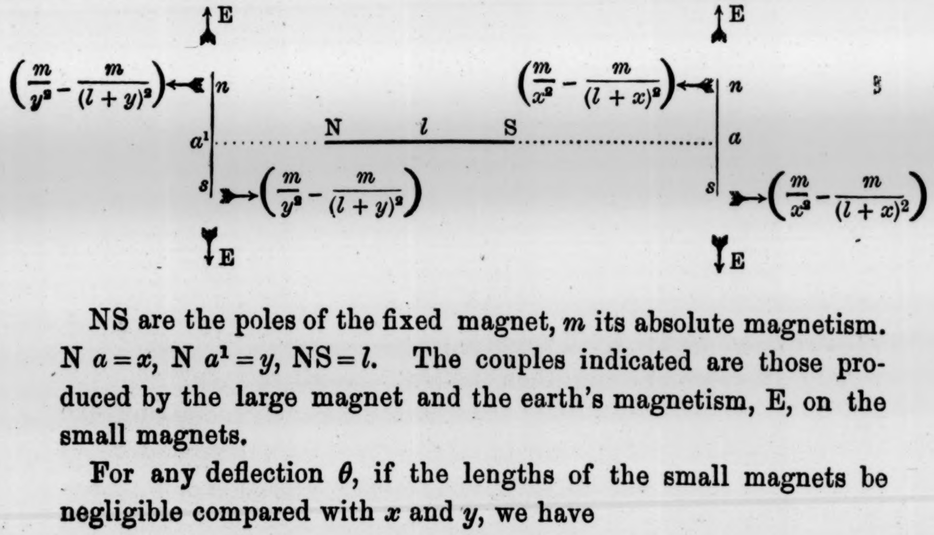
* For all four salts formulæ are given, by means of which the conductivity of any solution may be calculated if its density is given.

In the same line as the magnet and on both sides of it were two small magnets. These were cemented to the backs of small concave mirrors, suspended by single silk fibres, and placed in glass cases to guard them against currents of air. The deflections of the small magnets were measured exactly as in the reflecting galvanometer; and from the nature of the arrangement, and the important fact made out from these experiments, viz., that even when the poles of a magnet are at different temperatures the magnetic strength is the same in each, it follows that the absolute magnetic strength in either pole of the large magnet is directly as the tangent of the angle of deflection of the contiguous small one, and, therefore, will be measured by the reading on the corresponding scale.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NS are the poles of the fixed magnet, m its absolute magnetism. N $a = x$, N $a^1 = y$, NS $= l$. The couples indicated are those produced by the large magnet and the earth's magnetism, E, on the small magnets.

For any deflection θ, if the lengths of the small magnets be negligible compared with x and y, we have

$$\mathrm{E} \sin\theta = m\left(\frac{1}{x^2}-\frac{1}{(l+x)^2}\right)\cos\theta \ \therefore m \ a \tan\theta.$$

$$\mathrm{E} \sin\theta = m\left(\frac{1}{y^2}-\frac{1}{(l+y)^2}\right)\cos\theta \ \therefore m \ a \tan\theta.$$

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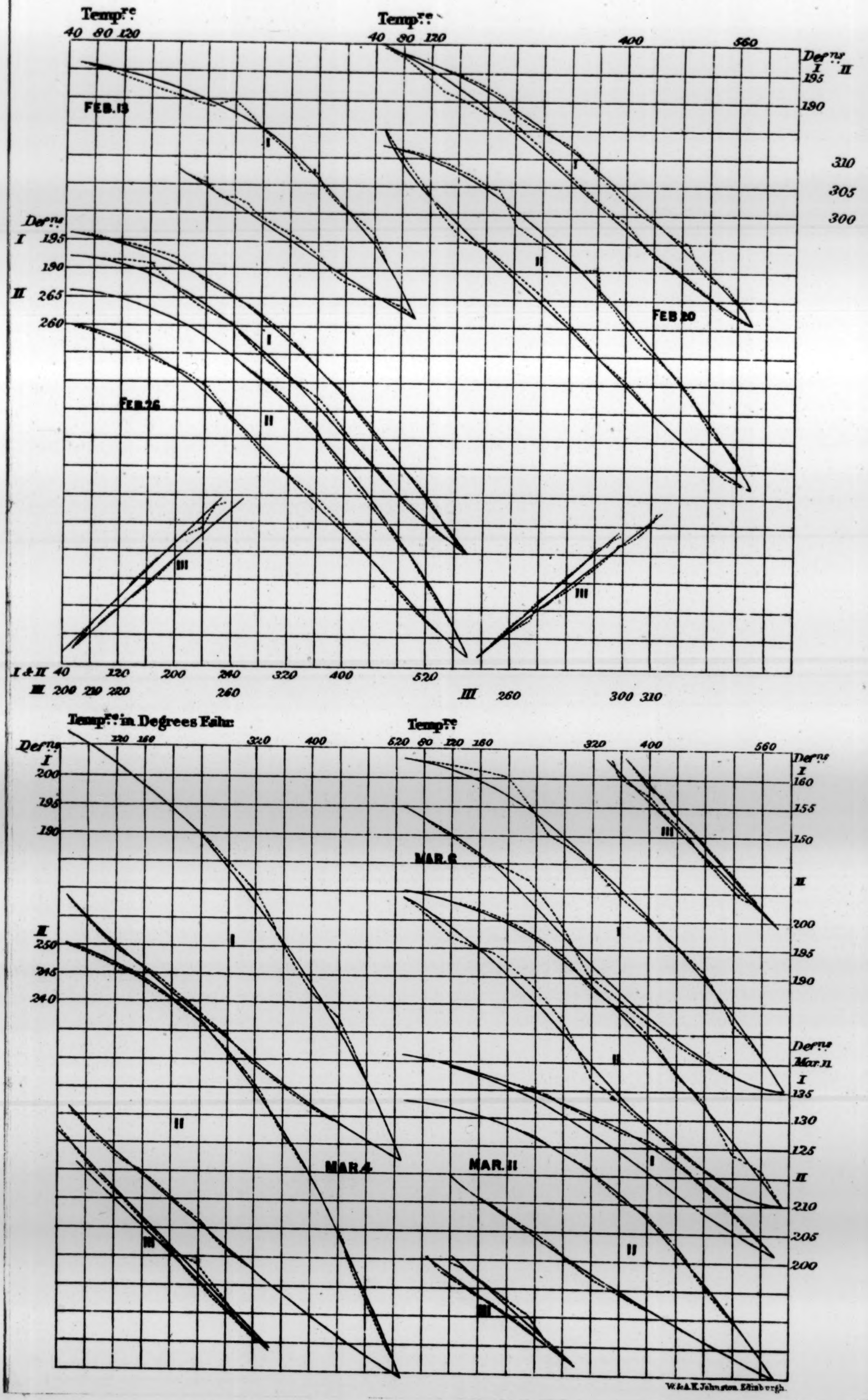

W. & A. K. Johnston, Edinburgh.

Curve I. of each day's experiment represents the rate of diminution of the hot pole in terms of its temperature; Curve II. that of the cold pole in terms of the temperature of the hot pole; and Curve III. shows how the magnetic strength of the one pole changes relatively to that of the other.

Perhaps the most important fact made out from these experiments was that already mentioned, viz., that whatever be the temperatures of the ends of the magnet, the magnetic strength is approximately the same in both poles. This was shown by plotting the deflections of the little magnets in terms of one another; for it was then found that the result was a straight line, which proves that the rate of diminution or increase of magnetic strength is the same in both poles; and, therefore, if they be of the same strength at the commencement of each experiment, when the magnet is of the same temperature throughout, they will of course remain the same during the whole experiment, when the poles are of different temperatures. (See figure III. of each day's experiment.) When the pole which had been heated was allowed to cool again, the line obtained by plotting the deflections of the two poles was still approximately a straight one, though not exactly coinciding with that obtained for it when being heated. This, however, is quite satisfactorily accounted for by the alteration of the zeros, which was never the same in both, and therefore the measured strength differed from the true strength more in one pole than in the other. In the first communication it was pointed out how the mere heating of the pot produced in some unaccountable way an alteration of zero. The fact that the poles are the same strength throughout also accounts for the general similarity of Curves I. and II. for each day.

It is to be observed that Curves I. and II. become smoother day after day, as if the boiling so altered the molecular constitution of the steel, as to enable it to conduct more easily a state of magnetic distribution.

It is interesting also to notice that the rate of diminution of magnetic strength decreases on each successive experiment, and that the two branches of each curve approach nearer and nearer to each other, thus showing a greater unwillingness on the part of the magnet to lose any of its magnetism permanently with heating.

The curves of March 4 represent an experiment in which the poles of the magnet were reversed, *i.e.*, what was before heated is now kept at the temperature of the room; and these curves show what a very great permanent loss was produced by the reversion, and also how much greater the rate of diminution of the magnetism was than had been in previous experiments. In after experiments, such as that of March 6, the permanent loss is not nearly so great, and there is also a remarkable decrease in the rate of diminution.

The curves of March 11 represent an experiment in which the poles were again reversed; and, from the approach of the branches, we see that the magnet, as it were, becomes accustomed also to this treatment, and evinces great unwillingness in losing its magnetism permanently. In this day's experiment there is a great dissimilarity between Curves I. and II. We may look for the explanation of this in the alteration of zeros, which possibly may be much greater in the one pole than in the other. This supposition is strengthened on looking at Curve III., where it will be seen the two branches are very widely separated.

Throughout these experiments we have to acknowledge the assistance which W. Campbell, Esq., has rendered us.

4. On the Physiological Action of Light. No. I. By James Dewar, Esq., and John G. M'Kendrick, M.D., of the University of Edinburgh.

The authors of this communication have more especially directed their attention to the problem of the specific effect produced on the retina and optic nerve by the action of light. Numerous hypotheses have been made from time to time by physicists and physiologists; but up to the present date, our knowledge of the subject is without any experimental foundation. For example, Newton, Melloni, and Seebeck, stated that the action of light on the retina consisted of a communication of mere vibrations; Young conjectured that it was a minute intermittent motion of some portion of the optic nerve; Du Bois-Reymond attributed it to an electrical effect; Draper supposed that it depended on a heating effect of the choroid; and Mosier compared it to the action of light on a sensitive photographic plate.

It is evident that, in accordance with the principle of the transference of energy now universally accepted, the action of light on the retina must produce an equivalent result, which may be expressed, for example, as heat, chemical action, or electro-motive power. It is well known that the electro-motive force of a piece of muscle is diminished when it is caused to contract by its normal stimulus, the nervous energy conveyed along the nerve supplying it; and similarly a nerve suffers a diminution of its normal electro-motive force during action. In the same manner, the amount and variations of the electro-motive power of the optic nerve, affected secondarily by the action of light on the retina, are physical expressions of certain changes produced in the latter; or, in other words, are functions of the external exciting energy, which in this case is light. Considerations such as these led us to form the opinion that the problem of what effect, if any, the action of light has on the electro-motive force of the retina and optic nerve, would require for its investigation very careful and refined experiment.

The inquiry divided itself into two parts,—first, to ascertain the electro-motive force of the retina and nerve; and, second, to observe whether this was altered in amount by the action of light. The electro-motive force of any living tissue can be readily determined by the method of Du Bois-Reymond. This great physiologist found that every point of the external surface of the eyeball of a large tench was positive to the artificial transverse section of the optic nerve, but negative to the longitudinal section. This he accomplished by the use of his well-known non-polarisable electrodes, formed of troughs of zinc carefully amalgamated, containing a solution of neutral sulphate of zinc, and having cushions of Swedish filter paper on which to rest the preparation. To protect the preparation from the irritant action of the sulphate of zinc, a thin film or guard of sculptor's clay, moistened with a ·75 per cent. solution of common salt, and worked out to a point, is placed on each cushion. These electrodes were connected with a galvanometer, and the preparation was placed so that the eyeball, carefully freed from muscle, rested on the one clay-guard, while the transverse section of the optic nerve was in contact with the other. By following Du Bois-Reymond's method, we have had no difficulty in obtaining a strong deflection from the eyes of various rabbits, a cat, a dog, a pigeon, a tortoise, numerous frogs, and a gold-fish. The deflection was frequently so much as to drive the spot of light off the galvanometer scale.

With regard to the second question, namely, whether, and to what extent, the electro-motive force would be affected by light, we found more difficulty. The method followed was to place the eyeball on the cushions in the manner above described, to note the deflection of the galvanometer needle, and then to observe whether or not any effect was produced on the impact of a beam of light, during its continuance, and on its removal. In a few of our earlier experiments, we used Du Bois-Reymond's multiplying galvanometer; but finding the amount of deflection obtained was so small that the effect of light could not be readily observed, we have latterly used Sir W. Thomson's exceedingly sensitive reflecting galvanometer, kindly lent us by Professor Tait. We met also with secondary difficulties, such as the dying of the nerve, the impossibility of maintaining an absolutely constant zero and an absolutely constant amount of polarity, the effects of heat, &c.; but these difficulties we have overcome as far as possible by the most approved methods. The changes in polarity of the apparatus occurred slowly, and could not be mistaken for the changes produced by the action of light, which we found occurred suddenly, and lasted a short period of time. It is also important to state, that the deflections we observed do not at present profess to be absolute, but only relative values.

About 500 observations were made previous to the date of this first communication, and we took every precaution to obtain accurate results. The effects of heat were carefully avoided by covering over the troughs on which the eye under examination rested, with a spherical double shell of glass, having at least an inch of water between the walls.

The results we have arrived at are as follow:—

1. The action of light on the retina is to alter the amount of the electro-motive force to the extent of from three to seven per cent. of the total amount of the natural current.

2. A flash of light, lasting the fraction of a second, produces a marked effect.

3. A lighted match, held at a distance of 4 or 5 feet, is sufficient to produce an effect.

4. The light of a small gas-flame, enclosed in a lantern, and caused to pass through a globular glass jar (12 inches in diameter), filled with a solution of ammoniacal sulphate of copper or bichromate of potash, has also produced a change in the amount of the electro-motive power.

5. The action of light on the eye of the frog is as follows:—When a diffuse light is allowed to impinge on the eye of the frog, after it has arrived at a tolerably stable condition, the natural electro-motive power is in the first place increased, then diminished; during the continuance of light it is still slowly diminished to a point where it remains constant; and on the removal of light, there is a sudden increase of the electro-motive power nearly up to its original position. The alterations above referred to are variables, depending on the quality and intensity of the light employed, the position of the eyeball on the cushions, and modifications in the vitality of the tissues.

6. Similar experiments made with the eye of warm-blooded animals, placed on the cushions as rapidly as possible after the death of the animal, and under the same conditions, have never given us an initial positive variation, as we have above detailed in the case of the frog, but always a negative variation. The after inductive effect on the withdrawal of light occurs in the same way.

7. Many experiments have been made as to effect of light from different portions of the spectrum. This was accomplished by causing different portions of the spectrum of the oxy-hydrogen lime-light to impinge on the eye. All these observations tend to show that the greatest effect is produced by those parts of the spectrum that appear to consciousness to be the most luminous, namely, the yellow and the green.

8. Similarly, experiments made with light of varying intensity show that the physical effects we have observed vary in such a manner as to correspond closely with the values that would result if the well-known law of Fechner was approximately true.

9. The method followed in these inquiries is a new method in physiological research, and by the employment of proper appliances, it may be greatly extended, not only with regard to vision, but also to the other senses.

Monday, 5th May 1873.

Professor KELLAND, V.P., in the Chair.

The following Communications were read:—

1. Notice of two Fossil Trees lately uncovered in Craigleith Quarry, near Edinburgh. By Sir R. Christison, Bart., President, R.S.E.

The late Mr H. T. M. Witham read in 1830 to this Society, and published three years afterwards in greater extension, an inquiry of much interest respecting two fossil trees found in Craigleith Quarry, a mile and a half from the north-west outskirts of Edinburgh. The general points of this inquiry are, that trees of very great size lie, completely fossilised, in the very compact sandstone of the quarry, at a great depth below the rock surface, slightly inclined to the dip of the strata, with their structure so finely preserved in the fossilising material as to be beautifully shown before the microscope, and recognised as that of the Pinaceous Family, and of the section to which belongs the existing Araucaria. These trees have been generally known to fossile botanists by the name of *Araucarioxylon Withami.* An opportunity having occurred this year of confirming and extending the inquiries of Witham, it has been thought right to take advantage of it, again through the medium of the Royal Society.

One of Witham's fossils (No. 1) was found in 1826, the other (No. 2) in 1830; but his researches regarded principally the second. Since the latter year four similar fossils have been uncovered by the operations of the quarrymen. One of these (No. 3) was exhibited for some time to the curious in a hut constructed over it for concealment. Another (No. 4) was removed by the late Mr Ramsay of Barnton, behind whose mansion several large fragments may still be seen. The fifth is said to have been first brought to light in 1858, and to have been subsequently covered with the detritus of the quarry, till it was lately uncovered again by the operations of the quarry having returned to its neighbourhood; and it now lies in its place half displayed to the extent of 22 feet. The sixth has been found only a few months ago in the very bottom of the quarry, where, for the present, little more is seen of it than a cross section, level with the containing rock. There was also lately found, not far from the second last fossil, but not at all attached to it, or otherwise proved to have belonged to it, a "branch," as the workmen thought, eight feet in length and five inches across. No trace has yet been found of what became of No. 3, or of either it or of No. 4 having been examined by any scientific inquirer.

The succeeding remarks relate cursorily to No. 4, at Barnton House, but chiefly to those now shown in the quarry, and to the so-called "branch."

Mr Witham's fossil of 1830 lay with its lower end downwards, without either branches or roots. The lowest 12 feet are still in excellent preservation in front of the Botanic Garden Herbarium-House; and what appears to be the next 18 feet is in equally good preservation before that part of the Museum of Science and Art now building. The fossil now principally shown in the quarry is somewhat curved, apparently from several fractures occasioned *in situ*. It lies in a west and easterly direction, slightly southward, with the cord of its whole visible length inclined to the horizon at an angle of about 60°, that of the surrounding rock being only 28°. As no record remains of what has been lost of its upper part, and the quarrying has not reached its termination below, its position in relation to that of the living tree cannot be positively settled. Its present top must be 120 feet under the upper surface of the rock of the quarry.* The other (No. 6), of which little more than the cross section is now visible,* seems to lie much in the same direction as the last, and at a similar inclination of 60° to the horizon, but where the dip of the rocky strata is 38°; and it must have been covered with at least 180 feet of the very hard Craigleith sandstone.

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* *June* 30, 1873.—The upper fossil, No. 5, has been pulled down, and is about to be removed to the British Museum. Four feet of the lower one, No. 6, have been conveyed to the Botanic Garden of Edinburgh. One block of the former is 14 feet in girth. The latter, which is rudely cylindrical, measures exactly 8 feet 9 inches in circumference. Its angle of inclination was accurately ascertained before removal to be 61°.

So much of the lowest visible part of No. 5 is uncovered, that its girth may be safely estimated at nearly 10 feet; but at 11 feet higher up it swells out, like some rugged old elms, and must measure considerably more.* The girth of No. 6, in the bottom of the quarry, is very nearly 9 feet. These are much greater trunks than Mr Witham's of 1830, which, at 12 feet from its root, now measures 27 inches by 17. It is considerably flattened along its whole length; but No. 4, at Barnton House, is comparatively little flattened; and those now visible in the quarry seem scarcely flattened at all.

The woody structure of the trees has been more or less perfectly preserved in all of these fossils. There is nothing under this head to alter in the description and delineations by Witham of the fossil found in 1830, and little to add. Many portions present little remains of vegetable structure, and others the appearance of mineral matters only, crystalline, and without any other structural character; but many exhibit in perfection the minute microscopical woody structure represented in Witham's drawings. No. 6, that most recently discovered, shows the woody structure perfect and undeformed, so far as yet examined, from circumference to centre; but it also contains some small cavities containing nodules of pearl-spar; and one considerable cavity has been found, which besides these nodules, has a lining of perfect crystals of calc-spar three-quarters of an inch across. The "branch" shows the woody structure best of all.

This specimen, of which there were originally 8 feet, is now reduced to 18 inches. Its transverse section is rudely semi-oval. Its end is ruggedly pointed. It had been covered all over with a thin coat of coal, of which more will be said presently. Under this the naked eye may see the longitudinal fibrous appearance of wood. A cross section takes on the colour and polish of fine black marble; and on the surface are dimly seen ten lines, marking the boundaries of annual layers, extending from the straight edge right across, from a tenth to half an inch apart, and on the whole parallel to one another. A thin section, made soon after this notice was read, proves that these really are the boundary lines of annual woody layers, the structure of which is beautifully shown before a common lens. Hence the supposed branch is not such, but a longitudinal sector of one, or possibly of a trunk.

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* See Note on p. 105.

All these fossils are covered with a black shining crust of brittle, caking coal, from a tenth to a twentieth of an inch in thickness, easily detached from the surface underneath. This substance, when heated, froths up very much, emits much white dense flame, cakes firmly, and burns slowly away, leaving only from 3·5 to 4·5 per-cent. of ash.

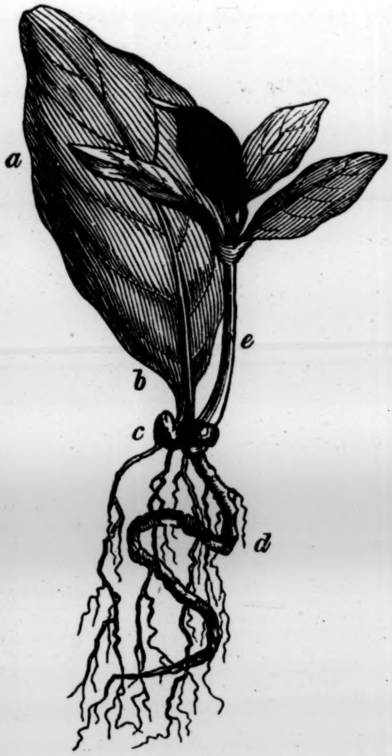
Under this crust the fossils are of a uniform grey colour, like our ordinary tertiary limestone. In most of them the fossilising material is very tough, and hard enough to strike fire with the hammer. No. 6, however, is dark grey, almost black indeed, till it is thoroughly dried, and not so hard as the others. It has evidently been long soaked in the moist bottom of the quarry. In all the mineralising material is essentially the same, and totally different from that of the containing strata. These are all a very pure, compact, fine-grained, extremely hard, siliceous sandstone. Witham has given no fewer than four analyses of his fossils, but they are all either erroneous or incomplete. Silica occurs, not uniformly, in rough particles, to all appearance adventitious, and amounting to about 0·5 per-cent only. Alumina is also present to about the same amount. But the great mass of fossilising matter consists of the carbonates of iron, magnesia, and lime, each in notable proportion. The relative proportion of these carbonates varies, even in different parts of the same fossil, the average being about 60 per-cent. of carbonate of lime, 17 of magnesia, and 14 of carbonate of iron in the form of protoxide. The proportion of the last ingredient varies most of all, for it sometimes rises so high as 28. The most interesting ingredient, however, is carbonaceous matter, which is always left after the solvent action of acids, in a proportion varying from 2·75 to 9·0 per-cent, and in a state of extremely fine division. This is not coal, like the external crust, but charcoal, burning away with a red glow, and no flame, and apparently not possessing the properties of graphitic charcoal. It sometimes occurs loose in cavities, two of which were found with a considerable loose lining of it.

Nothing has been found on the exterior of these fossils distinctly or even probably referrible to the bark of the original trees. This deficiency is explicable, if, as various circumstances seem to indicate, the trees did not grow where they lie, but have been water-borne, so that their bark, like their roots and branches, had been worn away. The outer crust of coal has been thought to represent the bark in such fossils, but that cannot be here; for, in the first place, it covers large surfaces of the trunk of No. 5, which are evidently the places from which lost branches had sprung; and, secondly, which is more to the point, it uniformly covers the blunt, rugged point, and the complete circuit, of the split sector, which was supposed erroneously by the quarrymen to be a branch entire in its whole circumference, and over the greater part of which it is impossible that there could have been any bark. It is difficult to say how this crust was formed. It is also a very difficult question to settle, how the carbon of this exterior crust was converted into coal, and that of the interior into charcoal. But further examination of such fossils may supply the answer, and throw some light on the process of formation of coal in general.

2. On the Formation of Buds and Roots by the Leaves of the Ipecacuan Plant (*Cephaelis Ipecacuanha*). By Professor Balfour.

The rapid propagation of Ipecacuan in India is an object of importance, and as such has occupied the attention of the Indian Government. The Edinburgh Botanic Garden has contributed largely to the stock of Ipecacuan plants now in cultivation in India. The plan of sending cuttings of the roots or rather rhizomes enveloped in moss has been very successful. We have been able in 1873 to send these cuttings in small boxes through the post. Dr Henderson, the present interim Director of the Botanic Garden at Calcutta, reports most favourably of this plan. He carried out to Calcutta in 1872 small boxes 8 inches by 2, containing germinating rhizomes of Ipecacuan, and roots of Jalap. These are now thriving under his charge. This mode of transmission will save much trouble and anxiety, and will insure an easy and rapid propagation of the plants. We may expect thus to secure for India a large supply of this invaluable remedy for dysentery.

In reference to the Ipecacuan plants recently sent to India in Wardian cases partly in earth and partly in moss, as well as in boxes with moss, Dr Henderson at Calcutta reports (18th March 1873) that the 120 plants of Ipecacuan taken by him from the Edinburgh Botanic Garden, have increased to 620 in three and a-half months and are all thriving. The smallest possible slice of the rhizome $\frac{1}{16}$th of an inch thick will form a plant. He has scarcely lost a single cutting. Mr Andrew T. Jaffray at Darjeeling, writes on the 19th March to the effect that he has now 7000 plants of Ipecacuan in cultivation.



In my communication last session to the Royal Society I stated that Mr Robert Lindsay, foreman in the propagating department of the Botanic Garden, had discovered that the petiole of the leaf of the Ipecacuan plant when put into the soil was capable of producing roots and buds. He has carried out the experiment fully, and I have to report the results. He states that leaves of Ipecacuan plants were removed with the petioles on 27th June 1872. Some were taken off close to the stem, while others were cut off above their attachment to the stem. They were inserted in sandy soil, and placed in a warm moist propagating house, and both gave out roots.

In about three weeks, the end of the petiole where it had been broken off or cut, was cicatrised and formed a rounded pea-like swelling. Shortly afterwards small fibrous roots were produced.

These after some time presented an annulated appearance, as shown in the preceding woodcut. Buds then began to arise from the rounded end of the leaf-stalk. In the woodcut a young shoot is shown arising from the petiole. Mr Lindsay tried to get buds from the leaves by simply placing them flat on the soil (like those of *Bryophyllum* and *Gesnera*), but in this he did not succeed. He found, however, that if the upper part of the leaf was cut off transversely, and the petiole was planted with only the lower half of the lamina attached to it, the growth of roots went on. But the upper half of the leaf when planted did not root. He also ascertained that, by cutting the leaf longitudinally through the midrib, and planting each half, he was able to get roots and buds from each of the halves after the wounds had cicatrised.

These experiments of Mr Lindsay demonstrate the facility with which Ipecacuan may be cultivated, and they supply useful hints to those who are superintending the growth of Ipecacuan.

Fresh specimens were produced, showing the result of Mr Lindsay's experiments, and drawings were exhibited, which had been executed by Mr Francis M. Caird, one of the assistants in the Botanical Class of the University.

EXPLANATION OF WOODCUT.

Ipecacuan Leaf with Petiole, Annulated Root, and young Plant. (From a drawing by Mr F. M. Caird.)

a. Lamina or blade of leaf.
b. Petiole or leaf-stalk.
c. Swelling at the end of the petiole after being placed in the soil.
d. Root proceeding from the swelling, showing an annulated form.
e. Young Plant arising from the swelling of the petiole.

3. On the Physiological Action of Light. No. II. By James Dewar, Esq., and John G. M'Kendrick, M.D.

Since the date of the first communication, we have endeavoured to obtain quantitative results involving time as a variable element in the case of the action of light on the retina and optic nerve. We have therefore found it necessary to construct a true graphical representation of the variations of the electro-motive force occasioned by the impact and cessation of light. It is clear that to register minute galvanometrical alterations, the only plan that could be employed would be to photograph on a sensitive surface, covering a cylinder rapidly revolving on a horizontal axis, the alteration of position of the spot of light reflected from the mirror, just as continuous magnetic observations are registered. As the apparatus required to execute these observations is very complicated, and would require much preliminary practice, we have in the meantime adopted a simpler method of registration. This plan is to note the position of the galvanometer at equal intervals of time, before, during, and after, the impact of light on the eye. In these observations we have used a seconds' pendulum giving a loud beat. One observer reads aloud the galvanometer, the other marks every interval of two and a half seconds, registers the numbers obtained, and regulates the supply of light. A little practice in the method above described has enabled us to obtain very satisfactory results, agreeing very closely in different observations, and showing in a decided way the salient points of the variation curve.

These curves show, that on the impact of light there is a sudden increase of the electro-motive force; during the continuance of light it falls to a minimum value; and on the withdrawal of light there is what we term an *inductive effect*, that is to say, a sudden increase of the electro-motive force which enables the nerve to acquire its normal energy. The falling-off of the electro-motive force by the continued action of light is the physical representative of what, in physiological language, is called fatigue; the inductive effect exhibiting the return of the structure to its normal state.

Occasionally the impact of light is not followed by a rise in the electro-motive force, but by a diminution. This is probably to be explained by the fact, that the death of the retina and nerve is indicated by a gradual falling of the electro-motive force, and that this change frequently goes on so rapidly that the impact of light is unable to produce any rise. In these circumstances, the spot of light, which before the impact of light was slowly moving downwards, is on the impact steadied for a moment, and then pursues its downward course more rapidly.

We have carried out, since last communication, several distinct sets of observations :—

1. We have proved that though there is no difficulty in obtaining a strong current from the skin of the frog, this current is not affected by light. This observation demonstrates that the pigment cells of the skin in the vicinity of the cornea have nothing to do with the results obtained.

2. The current obtained from a mass of the pigment cells of the choroid does not exhibit any sensitiveness to light.

3. The subcutaneous injection into the frog of Woorara, Santonin, Belladonna, and Calabar bean, does not destroy the sensibility of the retina to light.

4. As to the action of the anterior portion of the eye. On carefully bisecting an eye of a frog, so as to remove completely the anterior portion, including cornea, aqueous humour, iris, ciliary muscle, and lens, and on bringing the retina into actual contact with one of the clay pads, we readily obtained a large deflection, which was as sensitive to light as when the whole eye was employed, thus eliminating any possibility of the contraction of the iris under the stimulus of light having to do with the results previously obtained.

5. On using the anterior portion of the eye so that the cornea and posterior surface of the crystalline lens were the poles, we obtained a large deflection, which was, however, insensible to light.

6. The sclerotic and nerve without the retina, in the same manner, gave a large natural electro-motive force, also not sensitive.

7. The distribution of the electro-motive force between the different portions of the eye and cross section of the nerve may be stated as follows: The most positive structure is the cornea, then the sclerotic, then the longitudinal surface of the nerve; the cornea is also positive to the posterior surface of the crystalline lens, and the retina itself seems to be positive to the transverse section of the nerve.

8. As to *the effects produced by lights of different intensities.*—If a candle is placed at a distance of one foot from the eye, and then is removed ten feet, the amount of light received by the eye is exactly one hundredth part of what it got at a distance of one foot; whereas the electro-motive force, instead of being altered in the same pro-

portion, is only reduced to one-third. Repeated experiments made with the eye in different positions have conclusively shown that a quantity of light one hundred times in excess of another quantity only modifies the electro-motive force to the extent of increasing it three times as much, certainly not more.

9. It was apparent to us that these experiments would ultimately bear upon the theory of sense-perception as connected with vision. It is now generally admitted that no image, as such, of an external object, is conveyed to the sensorium, but that in reality the brain receives certain impressions of alterations taking place in the receiving organ. The natural query then arises—are the physical effects we have described and measured really comparable in any way with our sensational differences in light perception when we eliminate all mental processes of association, &c., and leave only perception of difference of intensity? In other words, are these changes the representative of what is conveyed to the sensorium? It would appear, at first sight, that this problem is altogether beyond experimental inquiry. There is, however, a way of arriving at very accurate measures of the variation of our sensational differences in the case of light, and this has been developed theoretically and experimentally by the justly renowned physiologist Fechner. Stating the law of Fechner * generally, we may say, the difference of our sensations is proportional to the logarithm of the quotient of the respective luminous intensities. A recent series of experiments by Dalbœuf † has entirely confirmed the truth of this law. If, therefore, the observed differences in electro-motive power, registered under conditions of varying luminous intensity, agree with this law of Fechner, regulating our sensational impressions, then there can be little doubt these variations are the cause of, and are comparable to, our perception of sensational differences. Now, we have stated above, that with a quantity of light one hundred times in excess of another quantity, the electro-motive force only becomes three times greater. According to Fechner's law, we may say the difference of our sensations, with that variation in the amount of luminous intensity, would be represented by 2, the logarithm of 100. Our experimental results being as 3 to 1, the difference is

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* Fechner, *Elemente der Psychophysik.* Helmholtz, *Optique Physiologique.*

† Recent Memoir to Belgian Academy.

also 2, thus agreeing very closely. It is to be remembered, however, that these results have been obtained by experiment on the eye of the frog, but similar changes have been observed in the eyes of mammals. In the latter, however, the amount of alteration is not so great, in all probability owing to the rapid death of the parts.

10. When one clay-point is placed in contact with the cornea or nerve, and the other with the section of the optic lobe, a current is at once obtained, which is sensitive to light. In this experiment the eye is left in the orbit, and the nerve is uninjured. Thus, the effect of light on the retina has been traced into the brain.

The following Gentlemen were elected Fellows of the Society:—

Donald Crawford, M.A., Advocate, Fellow of Lincoln College, Oxford.

M. M. Pattison Muir, Esq., Senior Assistant in the Andersonian Laboratory, Glasgow.

Monday, 19th May 1873.

D. MILNE HOME, LL.D., Vice-President, in the Chair.

The following Communications were read:—

1. On the Thermal Influence of Forests. By Robert Louis Stevenson, Esq. Communicated by Thomas Stevenson, Esq.

The opportunity of an experiment on a comparatively large scale, and under conditions of comparative isolation, can occur but rarely in such a science as Meteorology. Hence Mr Milne Home's proposal for the plantation of Malta seemed to offer an exceptional opportunity for progress. Many of the conditions are favourable to the simplicity of the result; and it seemed natural that, if a searching and systematic series of observations were to be immediately set afoot, and continued during the course of the plantation and the growth of the wood, some light would be thrown on the still doubtful question of the climatic influence of forests.

Mr Milne Home expects, as I gather, a threefold result:—1st, an increased and better regulated supply of available water; 2d, an increased rainfall; and, 3d, a more equable climate, with more temperate summer heat and winter cold.* As to the first of these expectations, I suppose there can be no doubt that it is justified by facts; but it may not be unnecessary to guard against any confusion of the first with the second. Not only does the presence of growing timber increase and regulate the supply of running and spring water independently of any change in the amount of rainfall, but, as Boussingault found at Marmato,† denudation of forest is sufficient to decrease that supply, even when the rainfall has increased instead of diminished in amount. The second and third effects stand apart, therefore, from any question as to the utility of Mr Milne Home's important proposal; they are both, perhaps, worthy of discussion at the present time, but I wish to confine myself in the present paper to the examination of the third alone.

A wood, then, may be regarded either as a *superficies* or as a *solid;* that is, either as a part of the earth's surface slightly elevated above the rest, or as a diffused and heterogeneous body displacing a certain portion of free and mobile atmosphere. It is primarily in the first character that it attracts our attention, as a radiating and absorbing surface, exposed to the sun and the currents of the air; such that, if we imagine a plateau of meadow-land or bare earth raised to the mean level of the forest's exposed leaf-surface, we shall have an agent entirely similar in kind, although perhaps widely differing in the amount of action. Now, by comparing a tract of wood with such a plateau as we have just supposed, we shall arrive at a clear idea of the specialties of the former. In the first place, then, the mass of foliage may be expected to increase the radiating power of each tree. The upper leaves radiate freely towards the stars and the cold inter-stellar spaces, while the lower ones radiate to those above and receive less heat in return; consequently, during the absence of the sun, each tree cools gradually downward from top to bottom. Hence we must take into account not merely the area of leaf-surface actually exposed to the sky, but, to a greater or less extent, the surface of every leaf in the whole tree or the whole wood. This is evidently a point in which the action of the forest may be expected to differ from that of the meadow or naked earth; for though, of course, inferior strata tend to a certain extent to follow somewhat the same course as the mass of inferior leaves, they do so to a less degree—conduction, and the conduction of a very slow conductor, being substituted for radiation.

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* Journal Scot. Met. Soc., New Series, No. xxvi., p. 35.

† Quoted by Mr Milne Home.

We come next, however, to a second point of difference. In the case of the meadow, the chilled air continues to lie upon the surface, the grass, as Humboldt says, remaining all night submerged in the stratum of lowest temperature; while in the case of trees, the coldest air is continually passing down to the space underneath the boughs, or what we may perhaps term the crypt of the forest. Here it is that the consideration of any piece of woodland conceived as a solid comes naturally in; for this solid contains a portion of the atmosphere, partially cut off from the rest, more or less excluded from the influence of wind, and lying upon a soil that is screened all day from insolation by the impending mass of foliage. In this way (and chiefly, I think, from the exclusion of winds), we have underneath the radiating leaf-surface a stratum of comparatively stagnant air, protected from many sudden variations of temperature, and tending only slowly to bring itself into equilibrium with the more general changes that take place in the free atmosphere.

Over and above what has been mentioned, thermal effects have been attributed to the vital activity of the leaves in the transudation of water, and even to the respiration and circulation of living wood. The whole actual amount of thermal influence, however, is so small that I may rest satisfied with mere mention. If these actions have any effect at all, it must be practically insensible; and the others that I have already stated are not only sufficient validly to account for all the observed differences, but would lead naturally to the expectation of differences very much larger and better marked. To these observations I proceed at once. Experience has been acquired upon the following three points:—1. The relation between the temperature of the trunk of a tree and the temperature of the surrounding atmosphere; 2. The relation between the temperature of the air under a wood and the temperature of the air outside; and, 3. The relation between the temperature of the air above a wood and the temperature of the air above cleared land.

As to the first question, there are several independent series of observations; and I may remark in passing, what applies to all, that allowance must be made throughout for some factor of specific heat. The results were as follows:—The seasonal and monthly means in the tree and in the air were not sensibly different. The variations in the tree, in M. Becquerel's own observations, appear as considerably less than a fourth of those in the atmosphere, and he has calculated, from observations made at Geneva between 1796 and 1798, that the variations in the tree were less than a fifth of those in the air; but the tree in this case, besides being of a different species, was seven or eight inches thicker than the one experimented on by himself.* The variations in the tree, therefore, are always less than those in the air, the ratio between the two depending apparently on the thickness of the tree in question and the rapidity with which the variations followed upon one another. The times of the maxima, moreover, were widely different: in the air, the maximum occurs at 2 P.M. in winter, and at 3 P.M. in summer; in the tree, it occurs in winter at 6 P.M., and in summer between 10 and 11 P.M. At nine in the morning in the month of June, the temperatures of the tree and of the air had come to an equilibrium. A similar difference of progression is visible in the means, which differ most in spring and autumn, and tend to equalise themselves in winter and in summer. But it appears most strikingly in the case of variations somewhat longer in period than the daily ranges. The following temperatures occurred during M. Becquerel's observations in the Jardin des Plantes:—

1859.

Date.	Temperature of the Air. °	Temperature in the Tree. °
Dec. 15,	26·78	32
„ 16,	19.76	32
„ 17,	17·78	31·46
„ 18,	13·28	30·56
„ 19,	12·02	28·40
„ 20,	12·54	25·34
„ 21,	38·30	27·86
„ 22,	43·34	30·92
„ 23,	44·06	31·46

* Atlas Meteorologique de l'Observatoire Imperial, 1867.

A moment's comparison of the two columns will make the principle apparent. The temperature of the air falls nearly fifteen degrees in five days; the temperature of the tree, sluggishly following, falls in the same time less than four degrees. Between the 19th and the 20th the temperature of the air has changed its direction of motion, and risen nearly a degree; but the temperature of the tree persists in its former course, and continues to fall nearly three degrees farther. On the 21st there comes a sudden increase of heat, a sudden thaw; the temperature of the air rises twenty-five and a-half degrees; the change at last reaches the tree, but only raises its temperature by less than three degrees; and even two days afterwards, when the air is already twelve degrees above freezing point, the tree is still half a degree below it. Take, again, the following case:—

1859.

Date.	Temperature of the Air. °	Temperature in the Tree. °
July 13,	84·92	76·28
„ 14,	82·58	78·62
„ 15,	80·42	77·72
„ 16,	79·88	78·44
„ 17,	73·22	75·92
„ 18,	68·54	74·30
„ 19,	65·66	70·70

The same order reappears. From the 13th to the 19th the temperature of the air steadily falls, while the temperature of the tree continues apparently to follow the course of previous variations, and does not really begin to fall, is not really affected by the ebb of heat, until the 17th, three days at least after it had been operating in the air.* Hence we may conclude that all variations of the temperature of the air, whatever be their period, from twenty-four hours up to twelve months, are followed in the same manner by variations in the temperature of the tree; and that those in the tree are always less in amount and considerably slower of occurrence than those in the air. This *thermal sluggishness*, so to speak, seems capable of explaining all the phenomena of the case without any hypothetical vital power of resisting temperatures below the freezing point, such as is hinted at even by Becquerel.

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* Comptes Rendus de l'Academie, 29th March 1869.

Reaumur, indeed, is said to have observed temperatures in slender trees nearly thirty degrees higher than the temperature of the air in the sun; but we are not informed as to the conditions under which this observation was made, and it is therefore impossible to assign to it its proper value. The sap of the ice-plant is said to be materially colder than the surrounding atmosphere; and there are several other somewhat incongruous facts, which tend, at first sight, to favour the view of some inherent power of resistance in some plants to high temperatures, and in others to low temperatures.* But such a supposition seems in the meantime to be gratuitous. Keeping in view the thermal redispositions, which must be greatly favoured by the ascent of the sap, and the difference between the condition as to temperature of such parts as the root, the heart of the trunk, and the extreme foliage, and never forgetting the unknown factor of specific heat, we may still regard it as possible to account for all anomalies without the aid of any such hypothesis. We may, therefore, I think, disregard small exceptions, and state the result as follows:—

If, after every rise or fall, the temperature of the air remained stationary for a length of time proportional to the amount of the change, it seems probable—setting aside all question of vital heat—that the temperature of the tree would always finally equalise itself with the new temperature of the air, and that the range in tree and atmosphere would thus become the same. This pause, however, does not occur: the variations follow each other without interval; and the slow-conducting wood is never allowed enough time to overtake the rapid changes of the more sensitive air. Hence, so far as we can see at present, trees appear to be simply bad conductors, and to have no more influence upon the temperature of their surroundings than is fully accounted for by the consequent tardiness of their thermal variations.

Observations bearing on the second of the three points have been made by Becquerel in France, by La Cour in Jutland and Iceland, and by Rivoli at Posen. The results are perfectly congruous. Becquerel's observations * were made under wood, and about a hundred yards outside in open ground, at three stations in the district of Montargis, Loiret. There was a difference of more than one degree Fahrenheit between the mean annual temperatures in favour of the open ground. The mean summer temperature in the wood was from two to three degrees lower than the mean summer temperature outside. The mean maxima in the wood were also lower than those without by a little more than two degrees. Herr La Cour † found the daily range consistently smaller inside the wood than outside. As far as regards the mean winter temperatures, there is an excess in favour of the forest, but so trifling in amount as to be unworthy of much consideration. Libri found that the minimum winter temperatures were not sensibly lower at Florence, after the Appenines had been denuded of forest, than they had been before.‡ The disheartening contradictoriness of his observations on this subject led Herr Rivoli to the following ingenious and satisfactory comparison.§ Arranging his results according to the wind that blew on the day of observation, he set against each other the variation of the temperature under wood from that without, and the variation of the temperature of the wind from the local mean for the month :—

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* Prof. Balfour's Class-Book of Botany, Physiology, chap. xii. page 670.

Wind, . .	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
Var. in Wood,	+0·60	+0·26	+0·26	+0·04	−0·04	−0·20	+0·16	+0·07
Var. in Wind,	−0·30	−2·60	−3·30	−1·20	+1·00	+1·30	+1·00	+1·00

From this curious comparison, it becomes apparent that the variations of the difference in question depend upon the amount of variations of temperature which take place in the free air, and on the slowness with which such changes are communicated to the stagnant atmosphere of woods; in other words, as Herr Rivoli boldly formulates it, a forest is simply a bad conductor. But this

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* Comptes Rendus, 1867 and 1869.

† See his paper.

‡ Annales de Chimie et de Physique, xlv., 1830. A more detailed comparison of the climates in question would be a most interesting and important contribution to the subject.

§ Reviewed in the Austrian Meteorological Magazine, vol. iv. p. 543.

is precisely the same conclusion as we have already arrived at with regard to individual trees; and in Herr Rivoli's table, what we see is just another case of what we saw in M. Becquerel's—the different progression of temperatures. It must be obvious, however, that the thermal condition of a single tree must be different in many ways from that of a combination of trees and more or less stagnant air, such as we call a forest. And accordingly we find, in the case of the latter, the following new feature: The mean yearly temperature of woods is lower than the mean yearly temperature of free air, while they are decidedly colder in summer, and very little, if at all, warmer in winter. Hence, on the whole, forests are colder than cleared lands. But this is just what might have been expected from the amount of evaporation, the continued descent of cold air, and its stagnation in the close and sunless crypt of a forest; and one can only wonder here, as elsewhere, that the resultant difference is so insignificant and doubtful.

We come now to the third point in question, the thermal influence of woods upon the air above them. It will be remembered that we have seen reason to believe their effect to be similar to that of certain other surfaces, except in so far as it may be altered, in the case of the forest, by the greater extent of effective radiating area, and by the possibility of generating a descending cold current as well as an ascending hot one. M. Becquerel is (so far as I can learn) the only observer who has taken up the elucidation of this subject. He placed his thermometers at three points:* A and B were both about seventy feet above the surface of the ground; but A was at the summit of a chestnut tree, while B was in the free air, fifty feet away from the other. C was four or five feet above the ground, with a northern exposure; there was also a fourth station to the south, at the same level as this last, but its readings are very seldom referred to. After several years of observation, the mean temperature at A was found to be between one and two degrees higher than that at B. The order of progression of differences is as instructive here as in the two former investigations. The maximum difference in favour of station A occurred between three and five in the afternoon, later or sooner according as there had been more or less sunshine, and ranged sometimes as high as seven degrees. After this the difference kept declining until sunrise, when there was often a difference of a degree, or a degree and a half, upon the other side. On cloudy days the difference tended to a minimum. During a rainy month of April, for example, the difference in favour of station A was less than half a degree; the first fifteen days of May following, however, were sunny, and the difference rose to more than a degree and a half.* It will be observed that I have omitted up to the present point all mention of station C. I do so because M. Becquerel's language leaves it doubtful whether the observations made at this station are logically comparable with those made at the other two. If the end in view were to compare the progression of temperatures above the earth, above a tree, and in free air, removed from all such radiative and absorptive influences, it is plain that all three should have been equally exposed to the sun or kept equally in shadow. As the observations were made, they give us no notion of the relative action of earth-surface and forest-surface upon the temperature of the contiguous atmosphere; and this, as it seems to me, was just the *crux* of the problem. So far, however, as they go, they seem to justify the view that all these actions are the same in kind, however they may differ in degree. We find the forest heating the air during the day, and heating it more or less according as there has been more or less sunshine for it to absorb, and we find it also chilling it during the night; both of which are actions common to any radiating surface, and would be produced, if with differences of amount and time, by any other such surface raised to the mean level of the exposed foliage.

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* Comptes Rendus, 28th May 1860.

To recapitulate:

1*st*, We find that single trees appear to act simply as bad conductors.

2*d*, We find that woods, regarded as solids, are, on the whole, slightly lower in temperature than the free air which they have displaced, and that they tend slowly to adapt themselves to the various thermal changes that take place without them.

3*d*, We find forests regarded as surfaces acting like any other part of the earth's surface, probably with more or less difference in amount and progression, which we still lack the information necessary to estimate.

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* Comptes Rendus, 20th May 1861.

All this done, I am afraid that there can be little doubt that the more general climatic investigations will be long and vexatious. Even in South America, with extremely favourable conditions, the result is far from being definite. Glancing over the table published by M. Becquerel in his book on climates, from the observations of Humboldt, Hall, Boussingault, and others, it becomes evident, I think, that nothing can be founded upon the comparisons therein instituted; that all reasoning, in the present state of our information, is premature and unreliable. Strong statements have certainly been made; and particular cases lend themselves to the formation of hasty judgments. "From the Bay of Cupica to the Gulf of Guayaquil," says M. Boussingault, "the country is covered with immense forests and traversed by numerous rivers; it rains there almost ceaselessly; and the mean temperature of this moist district scarcely reaches 78°·8 F. . . . . . At Payta commence the sandy deserts of Priura and Sechura; to the constant humidity of Choco succeeds almost at once an extreme of dryness; and the mean temperature of the coast increases at the same time by 1°·8 F."* Even in this selected favourable instance it might be argued that the part performed in the change by the presence or absence of forest was comparatively small; there seems to have been, at the same time, an entire change of soil; and, in our present ignorance, it would be difficult to say by how much this of itself is able to affect the climate. Moreover, it is possible that the humidity of the one district is due to other causes besides the presence of wood, or even that the presence of wood is itself only an effect of some more general difference or combination of differences. Be that as it may, however, we have only to look a little longer at the table before referred to, to see how little weight can be laid on such special instances. Let us take five stations, all in this very district of Choco. Hacquita is eight hundred and twenty feet above Novita, and their mean temperatures are the same. Alto de Mombu, again, is five hundred feet higher than Hacquita, and the mean temperature has here fallen nearly two degrees. Go up another five hundred feet to Tambo de la Orquita, and again we find no fall in the mean temperature. Go up some five hundred further to Chami, and there is a fall in the mean temperature of nearly six degrees. Such numbers are evidently quite untrustworthy; and hence we may judge how much confidence can be placed in any generalisation from these South American mean temperatures.

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* Becquerel, "Climats," p. 141.

The question is probably considered too simply—too much to the neglect of concurrent influences. Until we know, for example, somewhat more of the comparative radiant powers of different soils, we cannot expect any very definite result. A change of temperature would certainly be effected by the plantation of such a marshy district as the Sologne, because, if nothing else were done, the roots might pierce the impenetrable subsoil, allow the surface-water to drain itself off, and thus dry the country. But might not the change be quite different if the soil planted were a shifting sand, which, *fixed* by the roots of the trees, would become gradually covered with a vegetable earth, and thus be changed from dry to wet? Again, the complication and conflict of effects arises, not only from the soil, vegetation, and geographical position of the place of the experiment itself, but from the distribution of similar or different conditions in its immediate neighbourhood, and probably to great distances on every side. A forest, for example, as we know from Herr Rivoli's comparison, would exercise a perfectly different influence in a cold country subject to warm winds, and in a warm country subject to cold winds; so that our question might meet with different solutions even on the east and west coasts of Great Britain.

The consideration of such a complexity points more and more to the plantation of Malta as an occasion of special importance; its insular position and the unity of its geological structure both tend to simplify the question. There are certain points about the existing climate, moreover, which seem specially calculated to throw the influence of woods into a strong relief. Thus, during four summer months, there is practically no rainfall. Thus, again, the northerly winds when stormy, and especially in winter, tend to depress the temperature very suddenly; and thus, too, the southerly and south-westerly winds, which raise the temperature during their prevalence to from eighty-eight to ninety-eight degrees, seldom last longer than a few hours; insomuch that "their disagreeable heat and dryness may be escaped by carefully closing the windows and doors of apartments at their onset."* Such sudden and short variations seem just what is wanted to accentuate the differences in question. Accordingly, the opportunity seems one not lightly to be lost, and the British Association or this Society itself might take the matter up and establish a series of observations, to be continued during the next few years. Such a combination of favourable circumstances may not occur again for years; and when the whole subject is at a stand-still for want of facts, the present occasion ought not to go past unimproved.

Such observations might include the following:—

The observation of maximum and minimum thermometers in three different classes of situation—*videlicet,* in the areas selected for plantation themselves, at places in the immediate neighbourhood of those areas where the external influence might be expected to reach its maximum, and at places distant from those areas where the influence might be expected to be least.

The observation of rain-gauges and hygrometers at the same three descriptions of locality.

In addition to the ordinary hours of observation, special readings of the thermometers should be made as often as possible at a change of wind and throughout the course of the short hot breezes alluded to already, in order to admit of the recognition and extension of Herr Rivoli's comparison.

Observation of the periods and forces of the land and sea breezes.

Gauging of the principal springs, both in the neighbourhood of the areas of plantation and at places far removed from those areas.

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* Scoresby-Jackson's "Medical Climatology."

2. Observations and Experiments on the Fluid in the Cavities of Calcareous Spar. By Dr James Hunter and Edward Sang.

At a recent meeting I laid before the Society a short notice of a phenomenon exhibited by the fluid contained in the cavities of calcareous spar. This phenomenon had been observed only a few days before, and the notice was given for the purpose of directing to it the attention of other observers, and particularly of those who happen to possess other minerals with analogous cavities, and I now propose to give an account of some more recent experiments and observations in regard to it.

Of all known minerals, carbonate of lime presents the greatest facility for the study of the laws of crystallisation. We trace in it evidences of the stoppage and resumption of growth; we see marks of abrasion and fracture on surfaces once external but now covered over; layers of mud and portions of extraneous bodies are seen inclosed; yet amid all of these interruptions the direction of the planes of crystallisation are kept with remarkable persistence.

The ultimate or outer surface of a piece of Iceland spar of any great size presents a rough appearance, caused by the meeting of many surfaces of, as it were, smaller crystals; the hollows among these had not been filled up when the deposition ceased. If now there be an accession of liquid holding lime in solution, and the crystallisation be renewed, these hollows may not be filled up from the bottom, but may be covered over by the new mineral, leaving the spaces full of the mother liquid, so that when the whole mass has been cooled a small vacuity is left. Sometimes these cavities are very irregular, at other times their surfaces are beautifully flat and often obviously parallel to the cleavage planes of the spar. Hence, in mounting such specimens for microscopic observation, we must be careful not to heat, or at least not to overheat, the spar; cold cement is at all times preferable.

On looking at any object in the interior of a piece of spar we see two images, one belonging to the ordinarily, the other to the extraordinarily refracted light. Now, in all bits of spar containing faults, the crystallisation has been interrupted and carried on in various conditions as to temperature; hence the direction of the axis of crystallisation is not absolutely kept, as is obvious on any of the cleavage surfaces. Hence the path of the extraordinarily refracted ray is devious, and the image blurred; while the path of the ordinary ray, depending only on the homogeneity of the substance, is straight. For the purpose, therefore, of viewing anything in the interior it is proper to eliminate the extraordinary light by using a polarising reflector, a Nicol's prism, or something equivalent. This blurredness of the extraordinary image is common in crystals of other substances, and is due to the very same cause.

When a piece of spar containing a flat-faced cavity is placed under the microscope, and a small coin or other bit of metal is brought near it, the fluid is observed to take the opposite end of the cavity. For convenience a type-space was mounted on the end of a wire fixed to a stand so as to be readily brought into position, and the same repulsion was observed; here it seemed obvious that the metal and the spar had both the same temperature with the room, and thus there was no ground for suspicion that temperature had to do with the phenomenon.

Dr James Hunter, while repeating the trials, observed that a coin freshly laid down acted well, but that after some time its repulsion was less; he observed the same thing of a recently rubbed coin. This led him to suspect the agency of heat, and on repeating his trials it became clear that a difference of temperature is essential to the exhibition of this repulsion. He also found that any substance when warmed possesses the same property, and lost no time in communicating to me the result of his observations. This led Mr E. Elmslie Sang to suggest the trial of metal cooled below the temperature of the room; and, on returning home from the Society's last meeting, I found that Dr Hunter and my son had completed a set of trials showing most clearly that the fluid in the cavity moves from a warmer and toward a colder body. This may be very well shown by placing a piece of metal heated in the hand upon the spar, and so sending the fluid to the farther end. On now wetting the metal with ether, so as to cool it, the fluid is seen to come to the nearer end of the cavity.

This discovery by Dr Hunter completely changed the line of research in which I was engaged, and rendered any quantitative experiment excessively difficult, because we have no means of determining the temperatures of such small masses, and because a very slight difference of temperature is enough to produce the observed effect.

The statement that when A is warmer than B we have repulsion, but that when A is the colder we have attraction, cannot be universal, because if A and B were merely to change names the enunciation of the law would be reversed. Such a law can only hold good between members of two distinct classes, and, so far as we have yet seen, this distinction is between solids and fluids. Reflection on this matter brought to my mind a phenomenon with which I have been familiar for more than half a century, and which I used to refer to some peculiar variety of what is called *capillary action.* In preparing a small drill, such as is used by watchmakers, the little tool is first hardened by being plunged while red hot into cold water, and is then *tempered* or softened to the proper degree. This tempering is done by dipping the drill in oil or tallow, and then heating the stock end of it in a small flame. The oil is seen to gather in a drop, which moves rapidly towards the point, and the ebullition of this drop serves to mark the proper temperature.

If we coat a common smooth knitting needle with a film of oil so thin that it will not flow, and, holding the needle horizontally, bring the middle of it to the edge of a flame, we shall see a bulging mass of oil form on each side and move away from the flame, gathering bulk as it proceeds. Here we have a variation of the very phenomenon seen in the calc-spar; the fluid is repelled by the hotter metal. The experiment may be varied thus. Having placed the middle of a cleaned wire in the flame, put a small drop of oil on it near to the flame; this drop will be seen to move towards the colder part of the wire. Another variation is to prepare a thin metallic plate, and to coat its upper surface with a film of oil; when the middle of the plate is set upon a piece of hot iron, the oil gathers in a wave all round the hot part, and slowly recedes from it.

After having assisted at these experiments with the oil, Dr Hunter made a very beautiful variation, which consisted in directing a stream of warm air upon the end of the piece of spar under the microscope. The fluid recedes from that end, and the action is reversed by changing the position of the current.

On holding horizontally a glass tube, of which the inside has been thinly coated with coloured oil, and on heating a part of it, the oil is seen to leave the heated part and become heaped up on each side. The same thing takes place with water; but on making trial with sulphuric acid, no such effect was perceptible.

The occurrence of so many analogous phenomena points to some general or, at least, comprehensive law; and the question arises—Whether is this motion of the fluid dependent on actual contact, and due to the unequal heating of the adjacent solid, or is it a true repulsion between the colder fluid and the warmer solid, independent altogether of contact?

The instantaneous movement of the fluid when a warm body is brought near to without touching the spar, favours the latter interpretation of the phenomena, but the former interpretation seems to be more in accordance with the other variations of the experiments. If, when a warm body is brought near, the action be to induce an unequal heating of the containing vessel, and if the motions be due to the attractions or repulsions between the fluid and the spar, no real repulsion will be shown between the warm body and the total mass. But if the motion be due to a repulsion between the warm body and the colder fluid, the mass, as a whole, will be repelled. Hence, by poising the vessel containing the fluid so delicately as to allow of this repulsion being exhibited if it exist, we shall be able to determine the true nature of the action. In making the arrangements we must eliminate the influence of aërial currents caused by the difference of temperature. I am in hopes of being able soon to decide the question as between the two interpretations by help of an instrument of sufficient delicacy.

In making the experiments with glass tubes, it was noticed incidentally that when the glass has been so heated as to drive the oil or the water completely from it, the surface has acquired the property of not being easily oiled or wet again. I show one tube, over the surface of which the oil flowed easily; it has been hermetically closed, and has since that been heated. The oil now refuses to flow, and remains aggregated in oil-drops over the surface. When the glass in the proximity of one of these drops is heated, the oil is seen to creep away from the heated part, leaving behind it no trace of oil on the surface.

3. On "Tait's Property of the Retina."

By George Forbes, Esq.

Professor Tait having asked me to communicate to the Society some experiments I have made from time to time on the property of the retina discovered by him, and communicated to this Society, 15th January 1872, I prepared the following notes. It will be remembered that he pointed out that when the eye has been rested for a long time the first impression of light gives a red colour. Professor Crum Brown stated at the same meeting, that after Professor Tait had told him of the appearance he had himself observed a like phenomenon. Awaking one morning at grey dawn, and opening his eyes suddenly, he saw a glare of red on the window, and was so struck by it that he hastily rose to discover what house was on fire.

The circumstances under which Professor Tait made the observation were as follows:—He was suffering from sleepless nights owing to the illness arising from re-vaccination. He found that at each time of awaking, a portion of the wall feebly illuminated by a gas-flame appeared to have a crimson hue, and acquired its true white colour only after a few seconds of time.

I have very little to tell the Society, except to corroborate the evidence of Professor Tait, and to describe a method of observation that removes the necessity for re-vaccination or even sleepless nights. I have reproduced the appearance, I suppose, thirty times during the past winter. I lower the gas until there is only a small blue flame. This may be done before going to bed, and the experiment made in the morning, provided the window is darkened by shutters. In the morning, on suddenly turning up the gas, either the gas-flame assumes the crimson flush, or if there be a globe of ground glass on the gas, that globe assumes the hue. If the gas be quickly lowered again, a short rest is sufficient before repeating the experiment. It is never necessary (in my case) to be in the dark for more than an hour or so. But when the time of darkness is short, the crimson flush is seen only for a small fraction of a second. It is not necessary to have just awoken from sleep, though certainly this seems to favour the appearance, making it more extended and more lasting. The colour of this appearance is the same as that crimson flush which is often seen when the eyelids are closed and a light is shining on them. This struck both Professor Tait and myself, and led him to test whether it was due to the same cause, viz., the passage of light through the blood-vessels.

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I had proceeded thus far, and had moreover duly apologised to the Society for offering them a communication with so little novelty in it, when accident, or rather an inexcusable drowsiness, led me to perform some experiments that I look upon as of far greater importance, in that they give an extension to the property of the retina observed by Tait, in a direction quite unlooked for.

When travelling in the train from Edinburgh to London lately, I had my eyes closed, and frequently saw that crimson flush which is so often seen under such circumstances, and to which I have already alluded. This has been stated by Professor Tait and myself to be of the same hue as that observed by him in the cases mentioned in his note. It has always been attributed without any doubt to the passage of the light through the blood-vessels of the eyelid. But I soon noticed a remarkable fact, viz., that if the light of the sky remained of the same brightness, in other words, if the sun were not flitting behind clouds, this crimson flush gave place to a dingy orange or even yellowish brown colour. The brilliant crimson flush was in these circumstances seldom visible on closing the eyelids, and it invariably gave way to this dingy colour. On continuing to repeat this experiment, no doubt remained on my mind of the fact. Being now convinced that the appearance of white light passing through the blood-vessels of the eyelid is of this orange colour, I was at a loss to account for the crimson flush that is so often seen. I soon noticed, however, that when the eyes were closed, this brilliant colour never made its appearance, except at such moments as when the sun burst out from behind a cloud, thus brightening the field of view. I then covered my closed eyes with my hand, so as to cause complete darkness. If I now removed my hand, the eyelids still being closed the crimson flush made its appearance; the darkness having been continued for a considerable time. I soon found that if the closed eyes were first directed to a white handkerchief, and then to the bright sky, the crimson flush made its appearance. At this stage the true explanation of the phenomenon began to appear. It was that the colour of white light that has passed through the eyelid is dingy orange or yellowish brown, and that the crimson flush is due to Tait's property of the retina, namely, that *when the eye is suddenly illuminated, or when the illumination is suddenly increased, the retina first acquires the power of recognising the deep red; but the other colours usually follow so rapidly as to prevent this fact from being recognised.* I hope that Professor Tait will allow me to make this slight addition to his statement, as originally made.

According to this theory, the reason why this flush is only sometimes seen is, that peculiarly favourable circumstances are necessary for observing it. These are (1), a very long rest to the eye, (as this is how Professor Tait and Professor Crum Brown saw it); or (2), a very sudden illumination of the retina (this is the experiment of the gas-flame described in the first part of this communication); or (3), an exposure to a very feeble light after the eye has been in the dark for a short time (this is what I have just described). To prove still further that this, and not the transmission of light through blood, is the true explanation of the crimson flush as usually seen, I tried the following experiment:—A piece of common whitey-brown paper, four folds thick, was placed in front of one eye (the other being quite darkened). This shaded eye was kept dark for a short time, then keeping it closed to the skin to prevent stray light from entering, the head was raised, and the eye opened pointing to the sky. The crimson flush was unprecedentedly vivid, but soon yielded to the yellow colour of the paper employed. Lastly, six folds of plain white glazed writing paper were placed in front of the eye in the same manner. A longer duration of darkness was necessary than in the last case, but then the crimson flush was well shown, the colour then changed to orange, and it was some time before it assumed its natural white colour.

These experiments, then, prove that the transmission of light through the blood-vessels is not necessary for the production of the crimson flush, and that a long rest be given to the eye to perceive the phenomenon described by Professor Tait, and that the former depends upon the latter effect.

In the experiments last described the whole of the retina was affected. There is still one point that requires explanation. How is it that either a very powerful or a very feeble light is the most potent, either a gas flame or diffuse light that has passed through several folds of paper? At first this seems to militate against the identity of the two phenomena, but a little consideration explains difficulty. First, if the light be very bright, *e.g.*, a gas flame, the red will certainly have a greater tendency to appear, but it seems *a priori* likely that the other colours will also soon become apparent. Thus we should expect with a powerful flame to see a very intense redness, lasting a very short time. Second, if the light be very feeble, *e.g.*, diffuse light passing through paper. Here it is not likely that we should get so brilliant a red, but it is certainly very probable that it will be much longer before the other colours become sensible, since they are so feeble. We should expect then, in this case, to have a less powerful red lasting a longer time, but with the gas flame a strikingly brilliant flush, lasting a very short time. Again, with a medium light the green and blue colours would be added rapidly, and the crimson flush would not be powerful enough to be conspicuous in that short time. I may say that in every point this agrees exactly with the appearances as they are really seen.

4. A Theory of Volcanic Eruptions. By Daniel Vaughan.

From researches which have much engaged my attention for nearly twenty years, I am convinced that silica performs a very important part, not only in the formation of the earth's crust, but also in leading to violent subterranean movements. The low specific gravity of silicic acid, and of the rocks in which it predominates, would (if much of the internal earth were fluid) give rise to certain results, which I traced in an essay published in 1856, and also in a paper which was brought before the British Association for the Advancement of Science in 1861. In the latter, I have given reasons for believing that the invisible side of the earth's crust is very irregular in its structure; and that, as pressure promotes solidification, the great internal mountains must constantly increase in depression in consequence of the deposition on their peaks of solid matter of low density, and consisting either wholly or largely of silicic acid. I ascribed earthquakes to the occasional instability of such masses of new rock, as their size and buoyancy causes them to break loose from their fastening, and an ascending stony avalanche is driven against the weaker parts of the earth's crust.

But, on taking into consideration the great affinity of silicic acid for bases at a high temperature, volcanic phenomena may be traced to the collision of these silicious avalanches against such sedimentary rocks as contain carbonic and many other acids. Carbonate of lime, for instance, would not be decomposed by heat under the pressure it feels at great depths; but if a stratum of limestone were struck by a mass of incandescent quartz, or of highly silicified rocks, the resulting fragmentary mass would swell with the evolution of carbonic acid, and give rise to the various peculiarities observed in the eruptions and the upheaval of volcanic mountains.

5. On the Placentation of the Sloths. By Professor Turner.

After referring to the paucity of information on the placental characters of the sloths, and to the various inferences which had been drawn by anatomists from Carus's figure of the placenta of *Bradypus tridactylus*, some holding that it was cotyledonary and non-deciduate, others that it might have intermingled with it maternal deciduous substance, the author proceeded to describe his dissection of the perfectly fresh gravid uterus of a specimen of a two-toed sloth. This specimen, which was presented to him by Dr David Ridpath, only possessed six cervical vertebræ, and was referred to the *Cholœpus Hoffmanni* of Peters.

The author had succeeded in obtaining excellent injections both of the fœtal and maternal systems of blood-vessels. The placenta consisted of about thirty discoid lobes, aggregated together, and occupied about ¾ths of the surface of the ovum. These lobes could be peeled off the placental area of the uterus, and carried away with them a layer of deciduous serotina, the curling arteries, utero-placental veins, and a very remarkable system of intra-placental maternal sinuses, continuous with the uterine vessels, freely anastomosing with each other within the substance of the lobes, and lying between and in contact with the fœtal villi. Definite walls, distinct from the walls of the fœtal villi, could be traced around the sinuses. Crowds of red blood corpuscles were situated within the sinuses, and it was observed that many of these seemed to be nucleated, an appearance which had been recognised a few years ago by Kühne, Rolleston, and Moseley, in the blood corpuscles of the Tardigrada. This sinus system possessed a special interest, because it presented a gradation between the capillary net-work of the uterine mucous membrane, occurring in the diffused placenta of the mare or the cetacean, and the freely anastomosing cavernous maternal blood spaces seen in the highly concentrated human placenta. The amnion lay in close contact with the inner surface of the chorion, as in the human fœtal membranes. The fœtus possessed a special envelope, like that figured and described by Welcker, as investing the fœtus of *B. tridactylus*, and named by him an Epitrichium. Numerous additional details respecting the structure of the placenta and membranes are contained in the memoir.

The conclusions drawn from the examination of this placenta were, that in the sloths the placenta is not cotyledonary and non-deciduate as in the Ruminants, but in the fullest sense of the word deciduate. If the inference drawn by Huxley from Sharpey's observations on the structure of the placenta of *Manis* be correct, then, if the placental system of classification is to be of any value, the non-deciduate scaly ant-eaters can no longer be grouped along with the deciduate sloths in the order Edentata, which order will have therefore to be subdivided. The author then compared the placentation of the sloth with that of the other deciduate mammals, and pointed out a series of very interesting affinities between its placenta and that in the Primates.

Monday, 2d June 1873.

Sir ROBERT CHRISTISON, Bart., President, in the Chair.

The following Communications were read:—

1. On the Anatomy of a new species of Polyodon, the *Polyodon Gladius* of Martens, taken from the river Yang-tsze-kiang, 450 miles above Woosung. Part II., being its Nervous and Muscular Systems. By P. D. Handyside, M.D.

(*For a notice of Part I., see p.* 50).

The author showed to the Society a small entire specimen of the *P. gladius*, and next described, from a larger opened and dissected one, and from part of an adult fish, the spinal cord, the brain, the organs of the senses, and other parts of its nervous system. He illustrated his remarks by exhibiting four large drawings and nine smaller ones, including six microscopic views, explanatory of his description of the structure and disposition of the *spino-cerebral axis*, the encephalon as viewed from above and below, the ramifications of the encephalic nerves, and more particularly the structures subserving the senses of smell, sight, and hearing. A cartilaginous capsule forms *the olfactory* chamber, the mesial half of which is occupied by a fibrous disk composed of 29 septa which radiate from a prominent modiolus, and thus leave intermediate pituitary pouches, consisting of pigment cells and sarcole, invested with tapering, probably ciliary, epithelium. The choroid of *the eye* is connected with the exterior of the sclerotic by means of two large tubular processes that may be regarded, anatomically, as a modified form of the vaso-ganglion or choroid gland found hitherto in most osseous fishes only. The cysticule and utricule of *the auditory* apparatus are the only parts of the labyrinth that open into the cranial cavity,—differing thus from the generality of bony fishes and from sturgeons. A remarkable *sinus impar* is present, as in some osseous fishes; it is situated in the middle line of the skull, and connects the right and left vestibules through their upper walls.

Numerous cretaceous particles, of the nature of otolites, are studded over the interior of the walls of the cysticules and utricules; but none are found within the *sinus impar*, nor is the latter connected with either the air-bladder or with *atria* on the body of the atlas. Time did not permit of the author reading to the Society his paper in full.

The third part of Dr Handyside's paper will consist of an anatomical description of the viscera of organic life; and the fourth part, of the articular system and the endo-skeleton of the ***Polyodon gladius.***

2. On the Placentation of the Seals. By Professor Turner.

After pointing out that the observations of Alessandrini, Rosenthal, Eschricht, and Barkow on the placentation of the seals had been limited to the determination of the form of the placenta. and to the more salient facts connected with the arrangement of the fœtal membranes, the author in this memoir proceeded to describe systematically the gravid uterus, the form and structure of the placenta, and the arrangement of the fœtal membranes of the grey seal, *Halichœrus gryphus*. He was indebted to Dr M'Bain and Captain Macdonald of the cruiser "Vigilant" for the opportunity of acquiring the gravid uterus of a recently killed specimen of this seal. The distribution of the utricular glands was described. The affinities between the placentation of the seals and the proper carnivora, more especially the common bitch, were pointed out. Differences in the degree of deciduation in the various forms of placentæ were considered, and it was shown that the seal, as regards its placental structure, occupied a position intermediate between the non-deciduate mare and cetacean, and the more highly deciduate forms of placenta.

3. Second Report by the Committee on Boulders appointed by the Society. (With a Plate.)

In April 1871, this Committee was appointed for two purposes —one to ascertain the districts in Scotland where boulders of interest were situated; the second, to point out such boulders as were deemed worthy of preservation, with a view to an application to the proprietors of the land on which they were situated, to have them preserved.

The Committee, in fulfilment of the first of these objects, issued a number of schedules to the ministers and schoolmasters of Scotch parishes. The answers received enabled the Committee to present a First or interim Report to the Council of this Society; which Report was read at a meeting of the Society in April 1872.

The Committee have since continued their inquiries, and have obtained a considerable amount of additional information, the substance of which they propose to give in the following Second Report.

The additional information has been procured from three separate sources:—

1*st*, A considerable number of schedules, filled up by parochial ministers and schoolmasters, have been received by the Committee during the past year, several of which have been accompanied by sketches of the boulders.

2*d*, Special reports on particular boulders have been received from surveyors connected with the Ordnance and also the Geological Survey. These reports are particularly interesting.

3*d*, Your Convener, in a tour during last summer through some of the eastern and northern districts of Scotland, took an opportunity of inspecting some of the boulders mentioned in the schedules and reports received by the Committee, and ascertained many important facts.

The Committee, in order to record the information recently obtained, will follow the plan formerly adopted of specifying it for each county in alphabetical order, and in the briefest terms.

In now proceeding to explain the nature of the information received, the Committee desire to avoid as much as possible mixing up speculations with facts. But it is not easy to abstain from alluding to prevalent theories regarding the transport of boulders; nor would it be expedient to do so altogether, as it is desirable to show how far those theories seem to be supported or disproved by the facts ascertained.

I. BOULDERS.

1. From the statements appended to this and the First Report,

it will be seen that the boulders are divisible into two classes,—rounded and angular.

The boulders referred to are, of course, all "erratics," in the geological sense of the term, *i.e.*, they have been transported for considerable distances from a parent rock.

The rounded boulders are generally composed of rocks extremely tough and hard, and on this account were capable of undergoing great friction and rough usage without being broken up. Hence the round-shaped boulders most frequently consist of blue whin-stones, fine-grained granites, schists, limestones, and felspathic rocks.

The angular-shaped boulders, whilst embracing these rocks embrace also sandstones and conglomerates. Their angular shape of itself proves they could have undergone little or no rough usage by being rolled or pushed, for their angles and corners are in many cases sharp. Moreover, the rocks composing them are so loose and friable in texture, that they would have crumbled or been crushed to pieces had they undergone rolling or pushing.

The difference in shape between the two classes of boulders now referred to can be seen by looking at figures I., II., and V., as contrasted with figures IV., VI., and XIII. in Plate.

It may here, however, be proper to explain that some of the boulders composed of the friable rocks just mentioned, whilst angular and rough on one side, are sometimes rounded and smooth on the other,—a fact apparently indicating that after being carried to their present position without injury or mutilation, they had been subjected to friction or attrition on the particular side which is now smooth.

Some angular boulders are not cubical in shape, but are longer than they are broad; and in that case, the smoothed end, when there is one, is almost always narrower or more pointed than the rough end. It was a remark of Hugh Miller's, that on examining pebbles lying in the channel of a river, the great majority have their narrow ends pointing up stream. When once in that position, they retain the position longer than when lying broadside against the stream. This remark should not be lost sight of, in drawing inferences from the shapes and positions of boulders.

Examples of these angular boulders, with one end smoothed and pointed, will be noticed in Sketches VIII. and X.

It is not difficult to understand how boulders, originally cubical in shape, may undergo a change by the action of a stream of such a nature as to grind or smooth them. If fig. VIII represents a boulder cubical in shape when deposited, a stream coming against it in the direction of the arrow might break off or grind down the portion *a*, *b*, *c*, and leave the rest *a*, *c*, *f*, *e*, *d*, in the form of a boulder, smoothed and pointed at the *windward*, and rough at the *leeward* side.

That many of these boulders, after being brought to their present position, have been subjected to great attrition, is further proved by the markings on their surface. Scratches and sometimes deep ruts occur, not only on their upper surfaces, but also occasionally on their sides, as if indicating the passage over and along them, of stones harder than themselves, and pressed against them by some powerful agent or body. These scratches and ruts are most frequently in a direction coincident with the longer axis of the boulder, and show that the movement has been towards the boulder at its smooth and narrow end.

2. Another class of facts of some interest is connected with the positions of the boulders.

The rounded boulders, though frequently on the surface, are also, and perhaps more frequently, buried in mud, gravel, and sand-beds.

The angular boulders are occasionally found in these deposits; but they are much more frequently on the surface.

Angular boulders are very frequently on knolls or low hills, perhaps even more so than on lower levels. They are occasionally seen in clusters upon or round these knolls, as if the agent, whatever it was, which transported the boulders, had been obstructed in its further progress by the knolls, and had dropped them there.

As an example of this class of cases, reference may be made to the hill of Craigiebarns, about 1½ mile north of Dunkeld. This hill is about 1100 feet above the sea, and about 800 feet above the river Tay, which flows along its base. Four or five large boulders, mostly angular, lie on the top, or very near the top, of several rocky knolls which form the ridge of that hill. In like manner, there is a hill to the south of Dunkeld, also on the east bank of the Tay, with an angular boulder on the top of a rocky knoll.

Rounded boulders also occur on these rocky knolls, but not so frequently as angular boulders.

In connection with the fact of boulders being much clustered on and round rocky knolls, it may be noticed that boulders of large size, and especially angular boulders, are said to occur more frequently at high levels than at low levels.

On this point reference may be made to the report by one of the Ordnance surveyors from Boleskien in Inverness county, in which it is remarked that the hills in Stratherick reach to a height of 2900 feet, that the boulders are often perched on isolated hills, and that few boulders occur there below the level of 2250 feet.*

One of the largest angular boulders seen by your Convener (in Glen Lyon, Perthshire, and weighing above 100 tons), is at a height of 2500 feet above the sea.

It is proper, however, to add, that clusters of boulders do likewise occur at or beyond the mouths of valleys. In the Lochaber district, opposite to Loch Treig, in Spean Valley, there is a great accumulation of large boulders. So also in the valley of the river Nairn, to the east and below the mouth of Flichity Valley, there is a similar accumulation. In both of these cases the boulders lie on the top of debris, having all the appearance of moraines. These accumulations of boulders may be ascribed with great probability to the operation of glaciers. But that explanation cannot apply to clusters of boulders on or near the tops of hills.

3. Special notice deserves to be taken of the fact, that boulders of all sizes occur on islands, though in these islands no rock exists of the same nature as that composing the boulders.

In the First Report of the Committee several cases of that kind were reported from the Hebrides, as also from Orkney and Shetland.

In the statements appended to this Report, additional examples are reported.

Mr Campbell of Islay, in a document given in the Committee's last Report, says that many of the boulders on the western islands are "perched on hill tops," and have come from the northward in a direction "parallel to the run of the tides."

Appended to this Report, there is a similar opinion expressed, founded on the appearances in the small island of Foula (Shetland).

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* See Inverness, page 157

The gentleman who expresses this opinion, and reports on the Foula boulders, affirms unhesitatingly, that these boulders came from the mainland of Shetland, separated by a deep sea of from 16 to 18 miles in breadth; and he even specifies the hill from which the boulders have come.

So also the report from the Lewis is distinct, that there are boulders on the east shores of the island which must have come a distance of at least 35 miles across the sea from the mainland of Sutherland.

The important bearing of these cases of island boulders on the nature of the transporting agent, is evident. It is difficult to see how glaciers could have been instrumental in carrying *them.*

4. The information recently obtained by the Committee throws additional light on the *direction* from which the boulders have come.

(1.) As already mentioned, some boulders appear to have come down valleys, brought apparently on glaciers. Two localities are mentioned, viz., in Lochaber and in Nairn Valley, where such explanation may be accepted.

There are also probably places in Perthshire, Forfarshire, and Aberdeenshire, where boulders lie in valleys, or at the mouths of valleys, which belong to this class of cases. The nature of the rock composing the boulders being found to be the same as the rocks *in situ* at the head or along the sides of the valleys, the birth-place of the boulders may be readily and correctly assumed to have been there.

(2.) But there are hundreds of localities with boulders, to which this explanation is inapplicable. Not only boulders situated on islands, but boulders perched high up on hill-sides and near mountain-tops, seem to require a different explanation.

On the mainland of Scotland, at least in its eastern half, from which the Committee have received the fullest information, the angular boulders, and also many of the rounded boulders, appear to have come over a wide extent of country in one and the same direction, viz., from the north-west, crossing valleys and ranges of hills.

This inference had been drawn, years ago, from such facts as the finding of granite and mica-schist boulders in the counties of

Fife, East Lothian, and Berwick, which must have come from the Scottish Highlands. But farther and more striking proofs of this great north-west movement are afforded by the large boulders in the counties of Elgin, Nairn, and Ross-shire, of which accounts are given in the Appendix to this Report. From these, it appears that conglomerate boulders, from 30 to 50 tons in weight, now lying on the hill-sides and the plains of Elgin and Nairn, must have been somehow transported from the conglomerate hills of Cromarty, across what is now the Moray Firth; and that granite boulders, very little smaller, and many of them angular, situated in the district between Tarbat Ness and Tain, at various levels up to 1200 feet above the sea, must have been transported from mountains far to the north-west.

The non-occurrence of conglomerate boulders in this last-mentioned district is also itself negative proof corroborative of the north-west movement;—there being no conglomerate hills to the north-west of the last-mentioned places.

Whilst the existence of this north-west movement is indicated by the birth-places of the boulders, other circumstances confirm the conclusion. Thus, most of the boulders now referred to have their smoothest and sharpest ends towards the north-west; the scratches and ruts on their surfaces and sides point in the same direction; and where there are striæ on the rocks of the district near these boulders, these striæ also, in nine cases out of ten, are parallel.

It also deserves notice, that when boulders are on hills, they evidently indicate a preference for the sides of those hills having a north-west aspect,—a fact which seems to indicate the existence and prevalence of some transporting agent which could be more frequently and effectually stopped by the sides of hills facing the north-west.

The facts reported from Elgin and Ross-shire bearing on this point are corroborated by the position of the boulders described as on the hill on the north side of the Linnhe Loch at Fort-William.

But whilst there is strong evidence, so far as the Committee have proceeded in their inquiries, to show, that in a great part of the mainland of Scotland a general movement has prevailed from the north-west, some facts indicate a separate movement from the north-east. These are supplied partly from the Islands (Hebrides, Orkneys, and Shetland), and partly from the striations of rocks in different parts of Scotland. (See Reports from Lanark, Elgin, and Lochaber.) This north-east movement, however, does not appear to have been so general or so incisive as the north-west movement.

The Committee think it premature to draw conclusions with any confidence. They would only observe, that if two separate movements have taken place over the country, whereby rocks were striated, and boulders transported great distances across valleys, mountain ranges, and arms of the sea, it is most probable that these movements took place when the whole country was under the waters of a sea loaded with ice, and in which strong currents prevailed.

II. BEDS OF CLAY, GRAVEL, AND SAND.

1. Under this head, the most interesting fact brought out in the Reports lately received, is the occurrence at very high levels, of beds of boulder clay, gravel, and sand. They are to be seen in several parts of Scotland (chiefly the middle and north), at heights exceeding 2000 feet above the sea.

It can scarcely be doubted that the formation of these beds is due to large bodies of water. No marine organisms, it is true, have been found in these beds at or near this height; but it is difficult to account for them, except on the supposition that the whole country had been submerged to the depth of 2000 or 4000 feet. Currents, probably loaded with ice, have acted on the submerged mountains, and carried away from them an immense amount of debris, which has been deposited as sediment in the hollows, and forming the existing beds of sand, gravel, and clay.

When the land emerged, and for a long period after, there would be numberless lakes in the interior, among the mountains, formed of course by the rain which fell on their sides. In the course of time, the embankments of detrital matter which kept in the lakes would be cut through, and the lakes would sink in level. Most probably, when they so sank, beach lines would become visible on the sides of the mountains, like the famed parallel roads of Glen Roy.

Of these old beach lines there are many examples elsewhere than Glen Roy; and it is important to obtain reports of them, that they may be carefully examined.

Such terraces are visible in several parts of Flichity Valley, about 10 miles south of Inverness; and there also, the old detrital embankment still exists, which appears to have kept in the waters of the lake. It has been cut through by the river which now flows through Flichity Valley.

The whole of this valley deserves more particular examination, both with reference to these terraces, and with reference to the boulders, which lie in great heaps below its mouth.

In the valley of the Tay, between Pitlochry and Killiecrankie, there is a very instructive deposit of boulder clay and sand lying on the clay-slate rocks of Craig Ower hill, which forms here the east side of the valley. The deposit is well seen in two ravines, formed by mountain torrents, which have cut through the beds down to the rocks in one of the ravines, forming scaurs from 50 to 80 feet high. These scaurs show that, whilst the boulder clay presents only faint traces of stratification, if any, the beds of sand, which are in the heart of the boulder clay, are distinctly stratified Following the course of the most northern of the two ravines up from the Pitlochry road (about 350 feet above sea, and about 150 above the bottom of the valley), he found the above deposits all the way up, to a height of about 1350 feet above the sea. He saw that this deposit was continued along the valley towards the north, and he was informed by the Rev. Mr Grant, of Tennandry, the minister of the parish, who takes some interest in these investigations, that similar deposits exist on the flanks of Ben-y-gloe, a mountain three or four miles to the north-east, within the limits of this valley, and at levels several hundred feet higher.

This locality was also visited by another member of the Committee, the Rev. Mr Brown, who was much struck by the beds of sand and clay before referred to. He states that he made a minute search for organisms in the clay, thinking that if the beds resulted from marine currents, some remains, either animal or vegetable, would exist, but he found none.

Whether these beds were formed by the sea or by fresh water, it may be impossible at present to determine. But there seems strong reason to believe that the whole valley in this quarter was originally filled with detrital matter, which has since been carried away by the action of streams and rivers, except at a few places.

2. A question of considerable difficulty arises here in connection with the ancient glaciers which undoubtedly existed in Scotland.

Take, for example, Flichity Valley. If it was filled with a glacier which pressed on its sides, and carried down debris to form moraines, and the huge boulders which now lie on that debris, at what period did this glacier exist? Was it before or after the submergence of the country? If it was after the emergence, is it not likely that all the drift deposits of sand and gravel now on its sides would have been scoured out, and all traces of the terraces obliterated?

On the other hand, if the glacier existed before the submergence, is it likely that the moraines, in that valley, in Lochaber, and other parts of Scotland, would have retained so distinctly their prominent features? Would they not have been planed down by submarine currents?

It is, however, a circumstance in favour of the existence of glaciers before the submergence, that the striæ on rocks, which these glaciers are supposed to have produced, are often covered over by thick beds of sediment.

The Committee abstain from venturing farther upon theoretical ground. They allude to these questions only because the facts already ascertained, and more of which they will search for if they are re-appointed, seem calculated to throw upon these questions important gleams of light.

III. Work still before the Committee.

1. The Committee think that as so much information has been obtained from the east half of Scotland, it would be desirable to obtain similar information from the west half.

It is manifest from the Reports, that in the sea lochs of the west coast, there are boulders of large size, and in most interesting positions.

They are also particularly anxious to have as many particulars as possible regarding boulders on islands, especially if the boulders are composed of rocks not existing in the islands.

IV. Preservation of Boulders.

The Committee have not yet taken any special action towards the attainment of this object.

Perhaps it may be premature to do so, till they have obtained all the information which they expect regarding the localities where the most interesting boulders are situated.

Some doubt also is felt what would be the most judicious course of procedure. In Switzerland, as the Committee observe from the printed Reports which Professor Favre kindly sends to them as they are issued, very many boulders have been purchased by or for natural history societies and museum managers; and in one of the Reports, a form of the deed or conveyance is given, transferring a right of property in any particular boulder.

From these Reports, it appears that the boulders sought to be preserved are—1*st*, Those which have a traditional name. 2*d*, Those which have a legend attached to them. 3*d*, Those which possess scientific value,—for some reason which geologists point out.

Perhaps the Committee, in their selection of boulders to be preserved in Scotland, could not do better than act on these principles. But whether, to secure preservation, they will endeavour to obtain a transference of the property of particular boulders in favour of any Society, or whether they will merely endeavour to obtain from the proprietor on whose lands they are situated, a promise to preserve them, the Committee have yet to decide.

The Committee cannot conclude their Report without repeating the wish, which they expressed last year, that some of the many tourists who are likely to be, during the ensuing summer and autumn, in remote parts of Scotland, where large boulders still exist, may visit the boulders, with a view to report upon them to the Committee. The Committee, whilst desirous of obtaining additional information from all parts of the country, may be allowed to add, that there are three classes of boulders, as regards position, information about which would be particularly acceptable :—

First, Boulders on an island, at a considerable distance from the mainland, when these boulders have evidently been transported to the island.

Second, Boulders at very high levels on the mainland, or on or near the tops of mountains, to which they have probably been transported from a distance.

Third, Boulders along the north-west coasts of Scotland, say 50 miles on each side of Cape Wrath, with the view of ascertaining whether these boulders have come from the mountains inland, or whether (as believed by some geologists) they have come from some region sea-ward.

The Committee, in drawing attention to the importance of obtaining information regarding the boulders situated on the north-west coast of Scotland and on remote islands, know the difficulty of reaching these places by any of the means of conveyance accessible to the general public. There are, however, many gentlemen who have steam-yachts frequenting the western shores during the summer and autumn; and if they are disposed to assist this Committee in their researches, they might perhaps be induced to propose to a geological friend to accompany them on a cruise among the Hebrides, and give them an opportunity of visiting boulders not otherwise accessible. The Committee would be most grateful for any reports obtained in this manner, and would be very ready to acknowledge the service thereby rendered to geological research.

List of Boulders, Rocks, striated or smoothed, and Kaims, &c. reported to Royal Society Committee, arranged by Counties and Parishes.

ABERDEEN.

Kemnay.—Boulder, a fine grained blueish-grey granite called "The Souter's Stone," lying apparently in muddy sediment. Dimensions above ground 18 × 14 × 9 feet; but believed that as much below as above surface. Height above sea about 500 feet. Probably weighs 270 tons. This block on S.E. side of a hill running N. and S. for 500 yards, about quarter mile distant, top of which about 100 feet above boulder, and lies S.E.

of boulders described in Appendix to Committee's First Report. Country not suited for any glacier which could have brought "Souter's Stone," or any of the others. If "Souter's Stone" came from westward, it must have been floated and swung round by eddy into its present position. All the boulders in Kemnay and Chapel Garioch rounded and smooth on north and west ends, and rough at opposite ends. (Sketch of Souter's Stone, Plate No. II.)

ARGYLE.

Ardchattan.—Granite boulder, 14½ × 12½ × 5½ feet, partially rounded. One rut on top running whole length. Nearest rock of same kind is Ben Vreck, 3½ miles to eastward. Height above sea, 57 feet. Within 70 yards of boulder, a ridge of sand and gravel. Length, 1½ miles. Height of ridge varies from 50 to 100 feet. (Captain White, R.E.)

AYR.

Ardrossan.—Near Hunterston on shore, boulder 5½ × 11 × 6 feet and 26½ feet round, apparently grey compact granite, about 12 miles from Arran, and opposite to Great Cumbrae Island, 1¼ miles distant. (Robert Hunter, Hunterston.)

BERWICKSHIRE.

Berwick-on Tweed.—Castle Terrace. Boulder clay cut through for water pipes, and many boulders found, all more or less rounded, and composed of very hard rocks,—such as granites, gneiss, limestone, blue whinstone, greywacke, &c. The granites showed two varieties,—the common small-grained grey and red. (Observed by Convener.)

Burnmouth.—Near the railway station, among gravel, over greywacke rocks, a well-rounded lump of pinkish granite found by Convener.

This variety recognised by him as very similar to that used for a handsome chimney-piece in British Linen Company's Office, Edinburgh. Having ascertained that this chimney-piece supplied by Macdonald of Aberdeen, Convener sent to him a chip of boulder, that he might mention in what parts of Scotland the rock was found *in situ*. Mr Macdonald replied,—"The light-coloured pinkish granite in the British Linen Company's Bank came from the hill of Correnie in Aberdeenshire, not far from Kemnay. It was cut from boulders. But similar rock is to be had quite near. Rock very much the same appears about Kincardine O'Neil, in Deeside, and also about Ballater and Braemar. A similar stone is found at Beaufort, county Mayo, and most likely in other parts of Scotland and Ireland.

"Your boulder is very much akin to all these rocks; perhaps a little closer in the grain, but substantially the same.

"Many of the ocean-worn beach stones all along the coast to the south of this, are of the same granite as your boulder, or very much like it.

"I cannot lay my hands on a specimen sent to us, some years ago, from the Island of Uist; but if recollection bears me out truly, granite very much of the same character is to be got there."

Coldstream.—At the Hirsel (Earl of Home). About 120 feet above sea, boulder of white chert about 4 feet square, but very rough and irregular in shape. Found in a bed of gravel in making new avenue from Hirsel Policy to Coldstream. No rock of this nature known on north side of Tweed. It occurs at two or three places along the south of the Tweed, viz., at Carham and Nottylees; places bearing W. by S. from boulder, distant about 3 miles, with Tweed valley intervening.

As rock composing boulder friable, and its shape very angular and ragged, it could not have been rolled or pushed to its present site, nor could have been thrown down from any great height. Probability is, that when detached from parent rock, it fell upon ice, which floated it across valley.

Dunse.—On farm of Cockburn, a boulder of mica-schist well rounded. Is from 2 to 3 feet in length and breadth. An erratic from the Highlands of Scotland, and must have travelled at least 100 miles across many valleys and ranges of hills.—(First noticed by Mr Stevenson of Dunse.)

Foulden.—Several small boulders of coarse sienite (lying on old red sandstone), composed of red felspar, black hornblende, and small flakes of mica—nearest hill where similar rock, Cockburn Law—8 miles to N.W. Largest boulder, 5 × 3½ × 3 feet. Longer axis, N.W. Sharpest end points that way. (Convener.)

Greenlaw.—Marchmont (Sir Hugh H. Campbell). About 930 feet above sea, a blue whinstone boulder 9½ × 5 × 4½ feet, with faint striæ on top, parallel with longer axis. Original position of boulder slightly changed before being seen. This boulder must have come from westward. Rocks *in situ* Old Red. District not favourable to glacier theory. (Sketch by Lady Hume Campbell.)

Hutton.—Boulder of whinstone about 12½ tons found in clay of brickwork. Longer axis W.N.W. Sharpest end towards that direction. Probably from Hardens Hill, west of Dunse, 10 miles distant W.N.W. Striæ parallel with longer axis on one side. This boulder now in Paxton Policy grounds.

BUTESHIRE.

Big Cumbrae.—Rev. Mr Lytteil, Kilmarnock, pointed out to Convener many boulders of mica-schist on many parts of island. Rocks of island are Old Red. Largest boulder seen is near north end of island, at Balloch Martin, 12 × 6 × 3 feet. But as much more probably below ground. Longer axis N.N.E. Lies in a trough or valley running N.N.E. May have been floated through this valley from northward.

Little Cumbrae.—Rev. Mr Lytteil conducted Convener to highest part of island, north of Old Tower, 400 feet above sea. Rocks (claystone trap) here smoothed by some agent passing over from N. by W. Found several boulders of conglomerate and Old Red; none of mica-schist. Largest about 5 feet square, and rests on trap rock, by so small a basis that it may once have rocked. Known by name of "Bell Stane." Mr Lytteil supposes name derived from "Beltane" fires lighted here in Pagan times. Close to this stone, another smaller conglomerate boulder, with cup on it, apparently artificial, 4 inches diameter and ½ inch deep. Height above sea, 190 feet. Situated about 2 miles N.W. of old castle on east shore.

No old red or conglomerate rocks in island. Nearest are along shore at Rothesay, about 20 miles across sea to N.W.

Visited "Split Boulder," first mentioned by Smith of Jordanhill. A claystone trap, similar to rock of island. Lies at sea-level on rocks smoothed and striated, forming east side of a trough or valley running N.E. by N. Striæ run same way.

DUMBARTON.

Luss.—Mica-schist boulder on west bank of Loch Lomond, 26 × 18 × 7 feet; about 250 feet above sea-level. Situated on a brook entering Fruin Water, west of Callendoun Farm House. Longer axis E. and W., with sharp end to west and thick end to east. Rocks adjoining, old red sandstone. Nearest mica-schist hills to north and west, about 5 miles off. Reporter remarks, that if boulder came from W. or N.W., it must have crossed hills from 1000 to 2000 feet high. But it may have come from north, down valley now occupied by Loch Lomond, on ice which floated it so far south, and then carried it west up Glen Fruin.—(R. L. Jack, F.G.S., Alexandria.)

ELGIN.

Dyke.—Near west end of approach to Darnaway Castle, several granite and gneiss boulders from 2 to 3 tons each.

In same parish, near west lodge to Darnaway Castle, a kaim, quarter mile long, running N. and S. 12 feet above general surface. (Captain White, R.E.)

Elgin.—Boulder called "Carlin's Stone," on Bogton farm,—a coarse conglomerate, about 230 feet above sea. Imbedded pebbles, chiefly flesh-coloured quartzite.

About half a mile to N.W. a smaller boulder, called "Young Carlin's Stone."

Conglomerate rock occurs in hills to south, distant 5 or 6 miles; but of a variety different from that of boulders. Same variety of conglomerate as the boulders exists beyond Inverness to W., and in Ross-shire to N.W.

From size and shape of these conglomerate boulders, evident they must have been *carried* or *rafted.*

On other hand, in this district hundreds of round and smooth boulders of granite, gneiss, mica slate clay, slate, &c., whose shape and smoothness indicate that they have been *pushed* or *rolled* over the surface. These chiefly imbedded in gravel, clay, and sand.

To westward of these boulders a valley or depression runs in an E. and W. direction; Halldon or Pluscardine Hill being on south, and Carden Hill on north side. This valley opens out to westward.

Pluscardine Hill on its north slope dipping towards valley, covered with boulders which apparently deposited on it from some agent that came from N.W., and which obstructed by the hill.

Carden Hill has a flat ridge running about E. and W. This ridge consists mostly of a bare and hard gritty sandstone rock. It has been evidently ground down and smoothed by hard and heavy bodies passing over it. Striæ observed in numerous places on Carden Hill, viz., W. by N., N.W., N.W., N.W. by W., N.W. by W., N.W. by W. The average direction was N.W. by W., and from the formation of striæ, agent which produced them, evidently came from north-westward.

Numerous boulders along ridge of hill of granite (chiefly grey, one of red), gneiss, &c. The red granite boulder $4\frac{1}{2} \times 2\frac{1}{2} \times 1\frac{1}{2}$ feet. Its longer axis N.W. by W., and its sharpest end was towards that point.

Most of these boulders rounded and smooth, as if great friction and pressure had operated on them.

Some were lying along ridge on its northern slope, as if arrested in their further progress. Numbers also along ridge on south slope, as if pushed over hill, and put into positions where beyond reach of pushing agent.

At one place, sandstone rocks of ridge broken up, as evidenced by great fragments lying along southern slope, where beyond the reach of agent which broke and pushed them. These sandstone blocks lie at levels about 40 to 60 feet below level of ridge.

This flat ridge of Carden Hill extends for about a mile, and is about 400 feet above sea.

From ridge of this hill, the Carlin Stone boulder abovementioned seen, bearing S.S.E. about two miles distant. It is not probable that it came over Carden Hill. More probable, that it was floated through long valley between Pluscardine and Carden, in which case its course would be E.S.E., in conformity with prevailing movement in this district. Bottom of this valley from 130 to 140 feet above sea.

At one place on top of Carden ridge, N.W. striæ crossed by striæ from N. by E.; at another place, W. by N. striæ crossed by striæ from N.W. The N. by E. striæ seemed the older.

These variations in direction of striæ more reconcilable with idea of drift-ice than with glaciers.

Moreover, in this district no possibility of any local glacier from N.W.

From Carden Hill, Cromarty Firth bears about N.W., distant about 20 miles across sea. If a glacier brought these boulders from Ross-shire, it must have crossed Moray Firth, and risen over Carden Hill, and passed across valley on south of it obliquely.

If land submerged beneath an Arctic sea, and a N.W. current prevailed, possible to understand facts observable in this district.

Quarrywood Hill, about 200 feet above sea, and composed of sandstone striated on top. On N.W. slope four or five large conglomerate boulders about 140 feet above sea. Apparently from Ross-shire, and obstructed in further progress by this hill. (Convener much indebted to Mr Martin, Elgin, for pointing out facts above stated.)

Forres.—Conglomerate boulder, $9\frac{1}{2} \times 8 \times 8$ feet, about 44 tons, called "Doupping Stone," from legend of ceremony in admitting Forres burgesses; situated on Upper Caliper farm, about 580 feet above sea. Rock composing boulder evidently same as Carlin's Stone, near Elgin, being characterised by liver-coloured quartz nodules. This boulder situated on hill-side fronting Cromarty, which bears N.W. by N. across Moray Firth about 10 miles.

Informed by tenant of farm, that another boulder of same kind higher up hill, but so buried in earth that only upper part visible.

Forres to Nairn.—Extensive beds of sand and gravel, mostly stratified, shown in railway cuttings. Pebbles and boulders in these beds always rounded and smooth, seldom angular. Angular boulders apparently never imbedded entirely, almost always on surface.

Lossiemouth.—On old sea margin, 20 feet above present sea level, conglomerate boulder same as Carlin's Stone. About 1½ miles west of Caussie Lighthouse, a large boulder of silicated sandstone on a hill sloping to N.W. with N.W. striæ on it.

Inverugie limestone quarry, strata dip rapidly to north. On surface of rock, striæ running E. and W. This deviation from normal direction perhaps caused by dip of stratum.

In boulder clay over limestone rocks here, boulders of oolite found, which probably came from Ross or Sutherlandshire across Moray Firth.

Portion of an Oolite boulder seen by Convener, which found near Duffus school-house, about 125 feet above sea.

"Witch Stone," about quarter mile west of Duffus school, 250 feet above sea, viz., a large conglomerate boulder, exactly similar to Carlin's Stone, containing nodules of granite, gneiss, and purple-coloured quartz. Its longer axis N.W., and sharpest end towards that quarter. Hill on which lies, slopes that way. Lies on bed of sand.

On Clarkeley Hill, 1½ miles eastward of Burgh-head, hard sandstone rocks striated N.W. On same hill, several boulders of granite (both red and grey) and gneiss, lying on hill sloping to N.W. One of them, 4 × 3 × 2 feet, has its longer axis in same direction. They could have come only from N.W., and therefore across sea. (Rev. Dr Gordon, Birnie, pointed these out to Convener.)

HEBRIDES.

Iona.—Convener found on east side of island at the shore, small well-rounded boulder of conglomerate. Heard that similar boulders to be seen on west shore of Iona in St Columb's Bay. Conglomerate rocks, said to be *in situ*, at Inch Kenneth Island, forming cliffs 50 feet high, about 10 miles to N.E. The rocks in Iona are clay slate.

N.E. of Cathedral, on shore, hundreds of granite boulders (chiefly red variety). Several exceed 20 tons in weight.

Farther north, in a cultivated field, about 50 feet above sea, red granite boulder, weighing about 150 tons, called the "Geadh," or "Goose," 24 × 18 × 6 feet. Longer axis, S.E. (See Plate, Sketch No. IX.)

About ½ mile farther north, on east shore, another large red granite boulder, about 12 feet square. East end rests on clay-slate rocks of island. West end rests on a smaller granite boulder. Rocks below boulder decayed out, so that possible to creep under boulder. Groove on bottom of boulder running N.E. as if pushed over rocks from that direction. This boulder very rounded at angles, apparently from friction.

Boulder of red granite on side of highest hill in island, called "Dun Ii." Cubical in shape, and very angular, 22 × 16 × 16 feet. Boulder lies against steep slope of hill facing N.N.W., at height of 230 feet above sea.

Convener found red granite boulders of smaller size, at height of about 400 feet, the highest point of island.

Mr Allan M'Donald, schoolmaster, says that these granite boulders seem to be of same variety as that in Ross of Mull; but he thinks granite does not occur there so high as 300 feet. Ross of Mull bears from this spot S.S.E. The "Dun Ii" hill lies between Ross of Mull and this boulder.

When asked by Convener if any red granite in Islands of Tiree or Ulva, to north of Iona? Mr M'Donald said there was none.

Rocks on Iona more smoothed at the highest levels than at lower levels.

Smooth faces of rocks front N. by E. The rough faces all front south.

At south end of Iona a number of granite boulders (mostly red, but a few of grey variety) lying on the high ground, from 200 to 250 feet above sea. One of these standing up on end, leaning against a rock on S.W. side of boulder, showing that boulder came from N.E., and was obstructed by rock in its farther progress to S.W. (See Plate, Sketch No. XI.)

Most of boulders in south end of Iona lie with longer axis, N.E. and E.N.E.

Some of the boulders in this district in such positions, that they could not have come into them, except by floating ice, brought from northward, and by eddying currents.

In Ross of Mull granite of both red and grey varieties extensively quarried.

Heard of a large boulder on west side of island, in two fragments, which said to suggest idea of having been broken by falling from height.

Lismore Island.—Convener found several boulders of granite, both red and grey, which supposed to come from the Kingairloch hills to north. Almost all the large boulders broken up.

Staffa.—Convener found several small boulders of red granite on surface. No rocks of granite *in situ* here.

Stornoway.—Boulder 15 × 7 × ? of old Cambrian rock, very hard, and close in texture. Boulder now blasted. Rested on gneissic rock, and differed from any rock in the Lewis. Height above sea, about 50 feet.

The whole hill at back of Nether Pyble strewn with small round stones of similar Cambrian rock.

In parish of Ness, from Lighthouse at the Butt, thousands of small worn boulders of Cambrian rock scattered over surface, even on highest points.

No Cambrian rock *in situ* nearer than mainland. The rock *in situ* gneiss. (Henry Caunter, Stornoway.)

INVERNESS.

Boleskien, Abertarff, and Dores.—1. Granite boulders of red and grey varieties, in great numbers, over district of Stratherrick. Well rounded. Largest, near farm-house of Dell, 20 × 10 × 7 feet above ground, and apparently as much below ground. Longer axis, N. and S. Another near Fall of Foyers, 12 × 6 × 6 feet above ground. Granite (grey) occurs *in situ.*

2. On hills from which rivers Foyers and Ness rise, a great many boulders of granite and schist. The granite boulders well rounded; the schist boulders angular. Several perched on tops of isolated hills.

Highest hills in district about 2900 feet above sea. The boulders extend down to a level of about 2250 feet. Few below this level except in beds of streams. (Captain White, R.E.)

Culloden Muir.—Duke of Cumberland's "stone," a conglomerate boulder with six sides, girth altogether not quite 60 feet, and height 6 feet. Longer axis W.N.W. Height above sea about 470 feet; a few faint traces of striæ running W. by N. Nodules seemed similar to, but not quite the same as, those of Elgin and Nairn boulders.

Croy (Village).—About ½ mile to S.W., and 320 feet above sea. A mica schist boulder 17 × 9 × 9 feet. Lies on hill sloping to N.W. (Convener.)

A kaim begins here, which said to run eastward through counties of Nairn and Elgin for 30 miles.

A conglomerate boulder called "Tom Riach" (Plate, Sketch I.), of following dimensions:—West side, 18 feet; north side, 21 feet; east side, 24 feet; south side, 21 feet; height, 20 feet. It stands in the middle of a plain or flat valley through which River Nairn flows. Rocks *in situ* are gneiss, and boulder apparently rests on this rock. A small portion of its under surface, resting on the rock, visible. It looks smooth, as if it had been pushed over the subjacent rocks; and there seemed grooves or scorings which coincided with axis of valley, which here E. and W. This boulder must have come from distance, and been carried by ice, of some kind. In higher parts of valley in which this boulder occurs, conglomerate rocks *in situ* exist. Not probable that this boulder could come from N.W., as in that case it would be carried over Culloden Muir, which 300 feet higher than boulder. Very probable that brought by glacier from westward. Ingredients of this conglomerate apparently not same as those in Elgin and Nairnshire.

On high plateau, 4 miles south of Inverness, at height of about 774 feet above sea, another conglomerate boulder, with a thin stratum of old red sandstone on top. Girth about 51 feet. Height, 9 feet. Longer axis N. and S. Kaim of gravel and sand to N. of boulder, about 900 feet above sea, running E. and W. being direction parallel with valley of Nairn. (These boulders shown to Convener by Mr Jolly, Inverness.)

Dallanossie (Parish).—Moy Hall estate, Dallry farm, Mr Fraser, tenant. Boulder, 30 × 18 × 9 feet, apparently a bastard granite; though rocks of adjoining district are also granitic, the boulder much darker in colour. Nearest rock *in situ* S.W. by S. about a mile distant. Boulder split into two unequal parts. Its Gaelic name is "Clach Schuilt"—meaning "Cloven Stone." Height above sea, 2090 feet. (Captain White, R.E.)

Duntelchak Hill, west of Inverness.—Top about 900 feet above sea. Rocks composing it, a coarse conglomerate. On N.W. side of hill, rocks ground down and smoothed;—on S.E. side of hill rocks rough and steep.

A granite boulder lying on N.W. slope of this hill, about 30 feet below top. Length 7 feet, width 4 feet. Longer axis N.W., and sharp end towards that quarter. (Convener.)

Flichity Valley.—Beds of sand and gravel seen on hills to south, about 1500 feet above sea. Not near enough to be examined. At east or lower end of valley, top of a rocky hill striated, in direction parallel with axis of valley, viz., E.N.E.

At Farr, in Nairn Valley, a continuation of Flichity Valley, near the Free Church, a most remarkable assemblage of boulders. Some rounded, but most of them angular. Many are about 7 feet square. No conglomerate boulders here;—all gneiss or mica schist. They mostly rest on gravelly detritus, which may have been moraines. Others (and these are round shaped) rest on a smoothed rocky surface of gneiss beautifully glaciated, and sloping down towards west—*i.e.*, looking up valley. (See Plate, Sketch No. XIII.) This glaciated rock—smooth towards west, and dipping at angle of 30°—is on its east side rough and vertical. Very manifestly these rounded blocks, glaciated rocks, and gravelly debris, indicated glacier action. Two valleys meet here, one (Flichity) bearing due west, the other (Duntelchak) bearing N.W. Both valleys deserve exploration, with reference to remains above specified.

At lower end of Flichity Valley (about 3 miles west of these boulders), a great embankment of gravel and sand, through which River Nairn has cut passage about 200 feet deep. Before this passage cut, a lake must have filled Flichity Valley, dammed back by the gravel accumulation. That such a lake existed, proved by terraces on hill sides of valley. *Query*, If a glacier filled this valley, and brought blocks and moraines to Farr Church, when did this occur? Any gravelly embankment, such as now exists at east end of Flichity Valley, would have been swept away by a glacier. Glacier must, therefore, have existed, and disappeared, before embankment formed.

The only solution of problem seems to be, that after glacier had filled valley, carrying down blocks and debris to Farr, land sank under sea, destroying glacier, but not disturbing position of boulders, or carrying away much of moraines.

In this Flichity Valley an isolated hill, about 1620 feet above sea. Near the top of hill, rocks (gneiss) on W. and N.W. sides present an appearance of having been rubbed and ground down; on its W.N.W., S.E., and E. sides, boulders of gneiss attract attention, not only from size, but from very precarious positions. Boulders evidently erratic, for though gneiss, they are different kind of gneiss from that forming hill, and, being rounded, they have undergone considerable friction before reaching present position. The hill remarkably precipitous where boulders situated, insomuch that if they had fallen from any height, they would have rolled down. To prevent this, boulders must have been brought close to side of the hill where now lie, and let gently or gradually down upon hill-side.

A sketch is given of one of these boulders, to show how near it is to a precipitous portion of the hill. (See Plate, Sketch IV.)

These boulders about 500 feet above bottom of the valley.

In descending from this hill top, along the north side four several horizontal terraces passed, separated from one another by about 100 feet less or more, having appearance of old beach lines. On these terraces the boulders more numerous than elsewhere. (Mr Jolly of Inverness, was guide to Convener).

On N.W. of Craig Phædrick Hill, Inverness, the hard conglomerate rocks bared, rounded, and smoothed, and sloping towards N.W., at about 500 feet above sea; on south side of hill, same rocks rough and vertical.

Transported boulders of gneiss, &c., on N.W. side of hill—none elsewhere.

Many of these boulders have sides sloping down to N.W.

On several parts of hill, especially east side, rocks (old conglomerate, coarse and compact) broken up into huge cubical masses, similar to Tomriach boulder (see page 158)—many much larger.

Above Clachnaharry, grooves on rocks, E. and W.—a direction parallel with Beauly Valley; might have been made by glacier descending valley, or by drift ice, if valley submerged.

A remarkable boulder here, 30 paces in girth, and about 15 feet high, and roughly estimated to weigh 100 tons;—probably that called by Anderson "The Watchman's Stone." Name very suitable, as it rests on a projecting part of coast, and extensive view from it. Situated on what appears a terrace of drift, about 73 feet above sea.

A very extensive sea-terrace, about 40 feet above sea, girds coast of Beauly Firth, and seems to be repeated at Lentran and Clunes Railway stations, towards Tain.

Fort-William.—Ascended hill on north side of Linnhe Loch. Along both sides of loch several terraces visible, running for some distance one above another,—viz., 20 feet, 110 or 120 feet, and 494 feet above sea. This hill, called Treshlik, covered by small pebbles, indicative of aqueous action.

This hill about 1566 feet above sea. It forms a ridge about ½ mile long, running W.S.W. and E.N.E. Rocks on north and west sides smoothed, as if by friction of some agent passing over them from W.N.W. No such appearances on any other side of hill.

But these smoothings confined to a line along hill, not reaching lower than about 60 feet from top, nor reaching higher than about 30 feet from top.

Large boulder of coarse granite on N.W. angle of hill about 1494 feet above sea. It is about 16 paces round, and about 8 feet high. Boulder rests on the edge of the stratified rocks of hill, viz., clay slate. (See Plate, Sketch No. VI.)

The boulder in composition resembles boulder on Cluny M'Pherson's lands. (See next page.)

This boulder on very precarious site. The hill here exceedingly steep. Boulder could not have been brought from any eastern point; for in that case, it would have rolled down hill.

It probably did not come from a point due west, because Blythe Hill bears due west, about 2 miles distant, and forms a large mass about 2500 feet above sea, which would intercept any agent moving towards Treshlik Hill. There are only two points from which boulder probably came, viz., from mouth of Linnhe Loch bearing from Treshlik Hill S.W. by W., or from Loch Eil bearing from Treshlik Hill N.W.

The preference must be given to the N.W. quarter, because of the numbers of other coarse granite boulders all along the north slope of hill, and of the smoothed rocks being on same side.

Highland Railway from *Forres to Kingussie* cuts through immense deposits of clay, gravel, and sand, up to a height of about 800 feet above sea. Some of these deposits are stratified. They are full of rounded blocks of all sizes.

At *Dava* station, on east side of railway, about 900 feet above sea, rocks facing N.W. show large extent of surface glaciated.

At summit level, viz., about 1080 feet above sea (north of Kingussie), stratified gravelly drift abounds.

At *Kingussie* (about 730 feet above sea), two sets of terraces visible on the sides of valley, one about 50 feet higher than other, indicating existence of a lake at some former period, and which had been drained by barrier confining it having been cut through by Spey. Ruthven Castle stands on an isolated mass of drift, which probably formed island in this ancient lake at summit level of railway, viz., between Dalwhinnie and Dalnaspidel, about 1430 feet above sea; beds of sandy gravelly detritus abundant, apparently remains of aqueous sediment; where cut through by burns, they form scaurs or cliffs 50 to 60 feet high. Mr Robertson, factor, Old Blair, states, in letter to Convener, that near summit level of railway at Drumnachdier and Dalnaspidel, there were extensive deposits cut through of "pure sand," "so fine and soft" that it could not be used for building. He adds, that at a spot a little higher, viz., 1480 feet above sea, there was found (from surface)—1*st*, A peat bed, 2 or 3 feet thick, containing *fir* roots; 2*d*, A layer of clayey gravel about 2 feet thick; 3*d*, A peat bed with decayed branches of *birch* and *hazel*, and no fir; 4*th*, Tilly gravel.

On Cluny M'Pherson's lands (about 6 miles west of Kingussie) two large boulders of a very coarse grained granite on south side of Spey. One boulder is 11 × 9 × 6 feet. Plates of mica in boulder about 1 inch square. Felspar, green in colour. Longer axis E. and W. This boulder lies on hill side sloping down to west. Height above sea about 1035 feet. The other boulder, about double size of previous one, about ¾ mile N.E. from it, and at height of about 1080 feet above sea; also on hill side sloping down to west. There are other boulders on this hill of smaller size.

Rocks of district are a variety of coarse clay slate.

The only hill in this district is Craig Dhu, situated to north about 4 miles, consisting of clay slate, and about 2500 feet above sea.

Nearest granite rocks situated to westward. In that direction a valley, down which these boulders might have come. The physical features, however, not favourable to glacier theory, from absence of any range of hills to southward.

At *Laggan Free Church,* a well-rounded granite boulder, lying on a glaciated and striated rock of clay slate, sloping down to west, facing upper part of valley. Boulder 9 × 6 × 6 feet; longer axis E. and W., which corresponds also with striæ on rock, and with general direction of valley at this place.

Kingussie.—Boulder called "The Big Ordan Stone," said to be whinstone, situated on hill 5 miles S.W. of Kingussie, and 2 miles from Newtonmore Railway Station, on Belville estate and farm of Etteridge. Shape angular. Longer axis, S.S.W. Has a deep hollow on top facing S.W. Greatest length (viz., on S.E. side), 13 feet 10 inches. Breadth at top, 8 feet 4 inches. Height, 8 feet 10 inches. No similar rock in district. Height above sea from 950 to 1000 feet. One legend is that Fingal used the stone for a putting-stone, throwing it from Craig Dhu, on opposite side of river Spey; another, that when Fingal wished to drink out of the Spey, he put one foot on Craig Roy (a low shoulder of Craig Dhu) and the other on Ordan Hill, but finding Ordan too low, he threw the boulder from Craig Roy that he might put his foot on it. (John Robertson, Old Blair.)

Inverie.—On road toward Arrar, about 2 miles to north, and at height of about 360 feet above sea, clay slate rocks smoothed and striated in a direction from N.W. by N.

Fell in with two boulders lying near each other on side of hill, sloping down to W.N.W., where sea situated, about one mile distant. In one case, boulder lying on clay slate rocks; in the other case, boulder so sunk that base not visible. First boulder 8 × 6½ × 4 feet. Longer axis N.W. Second boulder 9 × 5 × 4 feet. (Shown to Convener by James Baird of Cambusdoon.)

Both boulders apparently came from N.W., and intercepted in further progress by hill.

Fell in with another boulder, which broken into two fragments. Configuration of district indicates that it must also have come from N.W. Smaller fragment lies from rest of boulder at a distance of 4 or 5 feet and to S.E. A study of fragments creates impression that boulder has been broken, not by action of frost, but by falling from a height, which caused concussion.

On shore to west of Inverie House, several boulders of coarse granite, similar to Fort-William and Cluny M'Pherson granite. These Inverie boulders supposed to have come from Dunedin and Cairnmore Hills, about 10 miles to eastward, and at head of valleys opening to west coast. Opinion expressed to Convener that these boulders not so likely to have come down the Dhulochan valley as the Loch Nevis valley.

At Invergussern (about 8 miles north of Inverie), the valley has been, at its mouth near the sea, crossed by an immense embankment of gravel and sand, about 30 or 40 feet deep, lying over rocks.

The river has cut through this embankment, and also a portion of the rocks covered by it.

This embankment probably terminal moraine of a glacier or a submarine deposit, more probably the latter, as sandy, and in some places stratified. Its ridge is about 140 feet above sea. At one time it has served purpose of a dam to keep in lake, the successive levels of which are seen on both sides of valley.

At summit-level between Inverie and Gussern, viz., from 400 to 500 feet above sea, a flat or terrace visible, with a number of boulders on it.

KIRKCUDBRIGHT.

Borgue.—Boulder of red sienitic granite. Oblong in shape. Longer axis N.W. and S.E. Rests on a low hill of partially decomposed trap. Longest sloping side fronts N.W. The S.E. end vertical and rough. Girth at 3 feet above base is 23 feet. A line over and across boulder measures 16 feet. Rocks *in situ* at and near boulder are partly trap, partly greywacke.

No granite nearer than about 10 miles, forming a range of hills extending from Dalbeattie, east of boulder, to Creetown, west of boulder. (See Plate, Sketch No. XII.)

Formerly many similar boulders in parish, all now broken up. (Earl of Selkirk and Rev. Geo. Cook.)

LANARK.

Glasgow.—Near Possil, sandstone rocks covered by boulder clay. Two sets of striæ on rocks under boulder clay—viz., from N.W. and from N.E.; oldest from N.W., and caused by a more powerful agent, judging by length and depth of striæ. Boulders in clay, recognised by Mr John Young (Hunterian Museum) as from Kilpatrick hills to N.W., and Campsie hills to N.E.

At Brickwork, Garscube Road, sandstone rocks also striated from N.W. more deeply than at Possil. No striæ from N.E. Perhaps striating agent here intercepted by a hill to N.W., quarter of a mile distant, about 100 feet high. At this place, in boulder clay, numerous boulders of old conglomerate, grey granite, schists, &c., from Bonaw and Kilpatrick hills to N.W. (Convener.)

NAIRN.

Auldearn.—1. Conglomerate boulder called Grass Stone, 15 × 9 × 4 feet, rounded. Longest axis, N.W. Height above sea, 200 feet.

2. Grey granite boulder 6 × 5 × 4 feet, a few yards S.E. of No. 1, round and quite smooth.

3. Red granite boulder, about 1¼ miles south of Nos. 1 and 2.

Lowest axis N.W. Size 12 × 8½ × 8 feet; striated in various directions. Well rounded. 350 feet above sea.

The rocks of district old red. Nearest place, where rocks same as boulders occur, is in Ross-shire to N.W.

Thousands of smaller boulders, similar to the above, scattered over district, used for buildings. (Captain White, R.E.)

Kaim of gravel and sand, with steep sides. Average direction east and west, winding in usual serpentine way. Is here continuous for ¾ mile. Average height above adjoining ground 30 feet. Full of well-rounded and smooth pebbles and boulders from rocks of district.

Auldearn (Parish).—*Brightmoney*, Lathan Estate, south of Dalmore Free Church. Five conglomerate boulders all on ground, sloping towards N.W., about 200 feet above sea, and 1 mile distant. Partly buried in sandy drift.

Their longer axis N.W. They slope towards that quarter, and have a smooth surface; whilst S.E. ends rough and steep. If these blocks were originally, when brought to spot, cubical, as when detached from parent rocks, they would have this shape. If any strong current loaded with ice were to come from N.W., their angles on N.W. end might be broken off, so as give shapes they now have. (See Plate, Sketch No. VII.)

Cawdor.—Hill of Urchany, composed of granite rocks. Nevertheless, blocks of old red sandstone scattered over surface in such quantities, that used for building houses and dykes. These must have come from north, as sandstone rocks only in that quarter, about 2 miles distant, and at a lower level.

The following four conglomerate boulders seen:—

1. "Clach na Gillean," or "Young Man's Stone." Height 10 feet, and girth 54 feet. Height above sea, 687 feet. Some of its corners angular, on crest or summit level of Urquhany hill. (See Plate, Sketch No. V.)

2. "Clach na Cailleach," or "Old Wife's Stone," on same hill, but on side which slopes to west by north. Height 15 feet; girth, 54 feet. Height above sea, 581 feet.

3. "Clach an Oglach," or "Boy's Stone." Lies at east end of a kaim. Height, 9 feet; girth, 69 feet; above sea, 312

feet. (A gneiss boulder near it about one-fourth the size. Numerous smaller do.)

4. Oblong conglomerate boulder lying on a bank facing W.N.W. Longer axis W.N.W., 50 feet × 24 × 12 feet. (Shown to Convener by Mr Stables of Cawdor Castle.)

ORKNEY.

Mainland.—Mr Miller of Bin Scarth says, that a valley runs E. and W. across the mainland of Orkney, forming in its course the bed of the Lochs of Stennis and Stanay. There is no large boulder in this district, but on north exposure of the hills, there are small stones strewed over the surface, quite different from rocks *in situ*. The former are a white bastard freestone; the latter, old red sandstone or flag pavement.

There is evidence through all this valley, of it having been channel of a tidal strait. There are in it hummocks of sand, mud, and water-worn gravel. Below these, reporter found heaps of small sprigs, brushwood, and hazel-nuts, preserved in moss, similar to the submarine mosses and forests under the bays of Otterswick, Deersound, &c.

The comparatively recent elevation from under the sea of all this district, is evident. Traces also exist of dry land with forests and other produce not now suiting climate.

Reporter does not know of any large boulder in the Orkneys, except on Sanday Island.

Sanday.—Dr Smith, secretary to the Edinburgh Royal Physical Society, sends to the Committee the following extracts from a MSS. paper by the late Dr Patrick Neill, on the Shetland Islands, dated 26th January 1806:—

"'Moorstone of Sanda,' Island of Sanday, flattest and lowest of the Orkneys. Greater part only a few feet above sea. Near a place called *Saville*, and not far from Burness Parish Church, stands a large isolated mass of primary rock—an aggregate of quartz, whitish felspar, and black mica. These disposed in layers, so that when seen in the mass, they constitute a block of gneiss. I did not accurately make measurements, but roughly estimated weight at 12 or 13 tons.

"Rocks of Sanda are wholly secondary strata,—sandstones, sandstone flag, breccia, and limestone.

"The only primary rocks in Orkney are in the largest islands (Mainland or Pomona), close by sea-port of Stromness, above 30 miles distant from Sanda. Hill at back of Stromness seems granite, with outer coating of gneiss. The gneiss, which is similar in quality to the Sanda Moorstone, is traversed by dykes or veins of granite.

"About a mile to N.E. of Stromness secondary strata begin. From thence to Sanda only sandstone and limestone visible.

"From Stromness to Burness Church is at least 34 miles in a direct line.

"On supposition that this gneiss tumbler in Sanda formed part of Stromness hill, it must have passed over 15 miles of what is land, and 19 miles of what is sea, at present.

"The firths of Westra and Eda, between Stromness and Sanda, are of immense depth,* through which the waters of the Atlantic now rush with indescribable force towards east or German Ocean, at the ebbing of the tides."

Dr Neill adds that he cannot imagine how this boulder transported from Stromness to Sanda, except by "what Saussure has termed a debacle," "the rush of vast torrents," which, besides transporting the boulder, might "have also scooped out those hollows which are now the firths of Westra and Eda."

Stromness bears from Saville about W.S.W., and a straight line between the two places crosses not only several firths, but several islands. If the boulder came from Stromness, as supposed by Dr Neill, its transportation by *land* ice is inconceivable.

Statistical Account states that granite rock, passing into gneiss, runs through Stromness parish, forming a tract about a mile wide, and six miles long (vol. xv. p. 46); and that all the rest of Orkney Islands are sandstones of different kinds. It is added, that "rolled blocks of granite are found in these islands far from their original position" (page 210).

Whilst it is very probable that this Sanda boulder came, as

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* Admiralty charts show depths of water in these firths to be from 10 to 20 fathoms.

Dr Neill supposed, from Stromness, it is right to keep in view that granite and gneiss rocks abound to the N.N.W. in the Shetland Islands. Transportation by *land* ice from these remote islands seems also inconceivable.

Mr Miller, schoolmaster of Cross and Burness, reporting the above boulder in Sanda to Committee, says that it is 22 feet in girth, and is round in shape.

Stromness (Parish).—Two granite boulders lying on old red sandstone near manse. A range of granite hills six miles long situated to eastward. One of boulders is a mile, the other a quarter of a mile distant from these hills. One boulder 50, the other 100 feet above sea. Each boulder 3 or 4 feet in length, breadth, and height. (Reporter, Rev. Ch. Clouston.)

PERTH.

Blairgowrie.—Two miles west of town, on road to Essendy Bridge, a Druidical circle of 5 large mica-schist boulders, about 5 feet long, and 6 or 7 feet in girth.

Another boulder, 7 × 5 × 3 feet, lies on summit of steep acclivity on Woodhead Farm.—(W. S. Soutar.)

Granite boulder, 4 × 3½ × 3 feet, on side of Ericht, quarter mile N. of Blairgowrie, excavated in making mill lead. No rock of same kind nearer than 30 miles in Braemar range of hills to N.W. Height above sea, 200 feet. Numerous granite blocks found in excavating for foundations of houses in Blairgowrie.

Callander.—Gneiss boulder called "Samson's Putting Stone" on top of Bochastle Hill, two miles west of Callander, 14 × 9 × 9 feet. Longer axis N.N.E. Lies on coarse old conglomerate, viz., same bed or stratum which crosses Scotland from Dumbarton to Stonehaven. Boulder, judging by nature of rock composing it, must have come from north-westward. It occupies precarious position, being close to edge of a precipitous face of hill about 330 above valley, fronting W.S.W. towards Loch Katrine. It may have been lodged either by a glacier which descended from Loch Katrine, or by floating ice, when land submerged. About 50 feet below the above boulder, and on a very steep part of hill, another boulder.

6 × 4 × 4 feet, very angular, of gneiss, evidently also brought from westward. Several quartz boulders on hill, which also must have come from westward. (Convener.)—(See Plate, Sketch No. IV.)

Clunie.—Gneiss boulder 8 × 5 × 4 feet, with longer axis S.W. Gneiss boulder 10 × 6 × 5 feet, with longer axis N.W. Both boulders on tops of knolls, and must have come from Grampians 5 or 6 miles to N.W. down a valley. First boulder called "The Grey Stone." Height about 320 feet above sea.—(Robert M'Leish, schoolmaster.)

Dunkeld.—Craigiebarns Hill, to N.E. of town, visited; made it about 1000 feet above river Tay at Dunkeld Bridge, and about 1250 feet above sea.

Several boulders of mica-schists at and near top of hill, but chiefly on sides facing N.W. Rocks *in situ* also mica-schist, but not the same variety as boulders.

These boulders mostly angular and sharp in edges; only one or two rounded; among these one of a hard brown sandstone.

Greater number of boulders perched on top or sides of knolls than in hollows. Agent which transported them had been of such a nature as to be interrupted in its progress by knolls, and made to discharge its cargo of boulders on them. (One of these boulders shown in Plate, Sketch No. X.)

On this hill, rocks smoothed and striated in numerous places. These markings, when examined minutely, show a movement over the rocks, to produce them, from N.N.W. The longer axis of boulders, generally N.N.W., which is towards head of valley. But whether a glacier occupied valley, or floating ice, not clear.

On Craigiebarns, gravel found at the highest points.

On descending hill towards the river, observed on rocks the following directions of striæ, at the height specified:—

At 972	feet above river,	striæ,	direction of,	N. by W.
„ 700	„	„	„	N½E.
„ 648	„	„	„	N. by E.
„ 288	„	„	„	N. by E.

The axis of the valley at this place N.E.; therefore agent which produced striæ, seems to have been of such a nature as to fill valley; this agent in its upper part (where it overtopped sides of the valley) moved obliquely across valley, but in lower part (near the bottom of valley) it followed course of valley.

Hill on east side of River Tay, 2 miles S.E. of Dunkeld about 1200 feet above sea. Gravel and sand abound all over it, to top.

On a knoll of clay slate, saw boulder of gneiss about 650 feet above sea. It was on side of knoll facing N.N.W. Longer axis of boulder also N.N.W., and its sharpest end in that direction.

Saw another boulder of gneiss 6 × 3 × 2½ feet, lying on well-smoothed slate rocks. Longer axis N.W. Height above sea 1000 feet. Rocks evidently smoothed from N.W.

Some of rocks on this hill show smoothings from two separate directions; one from north (as if down Tay Valley), the other from west (as if down Bran Valley). The rocks of clay slate are exceedingly hard, so that their smoothing indicates tremendous friction.

A very extensive flat stretches south from Dunkeld about 260 feet above sea. Robert Chambers notices it, and says it is 280 feet above sea. A terrace at about the same height, visible on hill, skirting Tay on east side, half a mile S.E. of Dunkeld. Probably the sea formed both.

Fowlis.—Abercairney estate. Granite boulder weighing about 30 tons; about 500 feet above sea. Situated on north side of a valley running E. and W. Rocks *in situ* old red. This boulder, and some smaller near it, must have come from northwestward. May have come either by a glacier or by drift ice. Granite hills about 20 miles to N. and N.W. (Rev. Mr Hardy, and Convener.)

Glen Lyon above *Invervar.*—Gneiss boulder (called "Clach na Salainn," from people who brought trees out of Black Wood of Rannoch resting them on the boulder), composed of six or seven large fragments. The whole mass about 30 yards round and about 3 yards high. May weigh about 120 tons. Rests apparently on coarse gritty sand. Must have been brought to present site by ice, and from northward. Height above sea about 2500 feet. On south side of summit level, between Glen Lyon and Rannoch, a cliff called the Scaur, half a mile to N.W. of boulder. Rocks *in situ* clay slate. If boulder came, as seems probable, from W.N.W., transporting agent must have passed on one side or other of Scaur. Configuration of hills here not favourable for glacier. Boulder within about one mile of summit level, which probably only 200 to 300 feet higher than it. Boulder may have been broken up by action of frost, or by having fallen from transporting agent. First theory not probable, as interior surfaces of fragments appear as weathered as any of the exterior sides of boulder.

About 500 feet below boulder, on banks of river Var, thick beds of boulder clay, sand, and gravel, full of rounded boulders, indicating aqueous deposits.

Hill on east side of Var, facing west, much covered by boulders, as if brought from westward by some agent, whose progress intercepted by hill. One of these boulders, known by name of "Clach na Tarbh," or Stone of the Bull.

Killiecrankie.—On east side of Killiecrankie Glen, on Fascally Estate, two ravines, parallel to one another, show very high cliffs of detrital matter full of large boulders. In the southmost of the two ravines, the scaurs are about 100 feet high.

These scaurs in the higher parts of the ravines show sections of stratified sand and fine gravel to a large extent. Traced these up to a height of about 1570 feet above sea (by aneroid). Was told by Rev. Mr Grant, of Tennandry, that at or near the hill of Ben y Gloe, there are beds of sand and gravel at a still higher level.

Some of the boulders in the most northern of these two ravines, which had fallen out of the drift deposits, were of large size; one, on being measured, showed 12 × 6 × 5 feet.

The following kinds noted:—Granite, grey, fine grained; granite, red, very coarse grained; gneiss, quartz, porphyry, limestone, primitive.

There is a large angular limestone boulder at the Pass of Killiecrankie, about ½ mile north of Tennandry mass, sticking in boulder clay about 856 feet above sea. These limestone boulders supposed to have come from Ben y Gloe, or some other mountains to the north.

Killin.—Ascended hill west of, made it 1350 feet above Loch Tay, and therefore about 1650 feet above sea. Sides of this hill, at least that facing eastward, covered with sandy detritus; but could not discover whether stratified or not. This detritus here reaches to foot of some steep rocky crags, at height of about 1000 feet above loch. But on adjoining hills descried through telescope, sandy deposits at least 500 feet higher.

At height of about 1090 feet above loch, rocks of hill exhibited effects of friction by action of some body pressing against them from a direction W. by S., viz., down the valley. Rocks facing east were uniformly rough.

If it was a glacier which effected this smoothing, the drift deposits on hill sides must belong to a period subsequent in date, as glacier would have scoured them all away.

On north side of Loch Tay, an extensive flat about 400 feet above loch, with appearance of a similar flat on opposite side.

Schehallion ascended.—Rock composing it, a very hard sandstone. The hill forms a long ridge running E. and W., the highest part of which at west end, viz., about 3560 feet above sea. The side of hill which seemed smoothest, faces N.W. by W.; but no striæ, or even any very clear proofs of a grinding action, seen. Gravel, indicative of aqueous deposition, seen up to a height of about 3000 feet.

Various small blocks of a fine grained grey granite scattered over surface up to a height of about 3000 feet. A similar rock said to be *in situ* at Loch Sunart to N.W.

On south side of Schehallion, at a height of about 2500 feet, rocks apparently ground down and smoothed, but not above this level.

In cliffs of the Burn courses on the south side of Schehallion, boulder clay noticed, up to a height of 1500 feet above the sea.

All the strath between Dunkeld and Pitlochry seems to have been a lake. Bottom of this lake indicated by a flat, through which Rivers Garry and Tummel have cut, to present channels. This flat is about 50 feet above these river courses at Ballinluig. Some miles farther south, this flat is from 80 to 100 feet above river. The barrier must have been to north of Dunkeld.

At the lower end of *Glen Tummell*, about ½ mile west of Bonskied House, there is a large amount of debris, exceedingly like a terminal moraine, with boulders lying upon it. But there was no opportunity to examine the locality.

Struan Railway Station.—Two boulders of gneiss on southern slope of hill, on left bank of the river Garry, east of station. Rock in channel of Garry also gneiss, but not exactly same. One boulder 12 × 6 × 7 feet. Longer axis N.E. and S.W. The other boulder 7 × 8 × 5 feet. (John Robertson, Old Blair.)

Ross.

Edderton.—Three large boulders of grey granite inspected by Convener, on hill south of manse, about 1000 feet above sea. These boulders on side of a hill sloping to N.N.W.

No. 1, about 910 feet above sea, and about 80 feet below a col or lowest part of the mountain range, called the "Stranger's Stone." If land submerged 2000 feet, a current probably existed, which, if from northward, and bearing ice, might carry boulders, and when ice touched hill-side would discharge them. Hill-side very steep at this place, so steep as to make it difficult to understand how boulder deposited without rolling down.

No. 2 boulder. About 710 feet above sea. Is situated on a sort of flat or terrace. Its longer axis (about 16 feet) points N. by E. General slope of hill here about N.E.

No. 3 boulder. Translation of its Gaelic name is "Big Lair of Fox." Height above sea about 752 feet. Situated on a well-marked flat or terrace, which bounded on south by a steepish cliff. Longer axis N. and S. General slope of hill here is to N.

The above three boulders clearly transported. Composed of granite—a grey variety. Rocks of hill on which rest, old red sandstone.

Where have they come from? The surmise that they came from "Cairn na Cunneig" seems improbable, if, as alleged, it consists chiefly of red granite.

The Rev. Mr M'Ewen, of Edderton, suggested the hills at or near Rogart, due N. or N. by E. from this spot about 10 or 12 miles, as the rocks there of grey granite.

These boulders not favourable to glacier theory. Their elevated positions, and the absence of any hills to the west or north nearer than 5 or 6 miles, are circumstances which render that theory almost impossible.

Rosskeen.—Ardross. Numerous large boulders, their longer axis nearly E. and W.

No. 1. March stone between Newmore and Ardross, about 50 feet in girth, and 8 feet above ground.

No. 2. At Achnacloich, at road-side, granite boulder 40 feet in girth.

No. 3. About half a mile above Ardross Castle, by way-side in a dyke, about 100 feet in girth, and 9 feet above ground.

No. 4. In a field opposite No. 1, of similar shape and size.

District between *Tain* and *Tarbet Ness.*—Shows on surface neither boulders, nor gravel, nor sand, but traces of mud, and occasionally of boulder clay, visible. At Fort-George, boulder clay reported 100 feet deep and more. Mr Stables, of Cawdor Castle, bored into it for water to that depth, and did not get through it.

If land was submerged 2000 feet, district about Fort-George, Moray Firth, Dingwall, Cromarty, &c., would be deeper than adjoining districts, and would be filled with muddy sediment, whilst shallower districts would be covered with gravelly and sandy sediment. The valley now occupied by Loch Ness and Caledonian Canal then a strait or kyle, through which tidal currents would pass; and if icebergs and drift ice came from westward, boulders and debris would be deposited on what are now the low lands of Moray, Banff, Elgin, and Ross, with the intervening Firths.

At Tarbet Ness, Balnabruach boulder visited, in company with Rev. George Campbell; a coarse reddish granite 33 feet in girth, and about 7 feet high. Longer axis E. and W. This boulder and another, not quite so large, near it, at sea level. Supposed to have come from "Carn na Cunneig" hill, which visible from boulder, bearing W.N.W. about 30 miles, with an area of sea between Tarbet Ness and coast near Tain, 10 or 12 miles distant.

An old sea margin visible here, about 11 feet above high-water mark, with several large boulders on it. When materials of old sea-cliff washed away by sea, these heavy boulders remained. Boulders on such terraces, when numerous, are thus indicative of aqueous erosion.

None of the boulders at Tarbet Ness are conglomerates. If transporting agent came from any points between W. and N.N.W. in Ross-shire, granite boulders both red and grey could have come to Tarbet. The conglomerate rocks are to the southward of the above line—viz., on Beauly River, higher parts of Strath Conon, Black Isle, &c.; and hence boulders taken from them, and moving S.E., would not cross Tarbet Ness, but would be carried towards Nairn, Elgin, and Banffshires, where actually found.

One of boulders (near Fearn parish school) has attached to it a Gaelic legend, the translation of which as follows:—

> "Grey stone of the clay hollow
> Makes three sommersaults
> When it hears the cock crow."

This boulder slopes downwards on its north side. It is also towards north, that land most depressed—viz., towards the sea.

Boulder of red granite 2 miles north of *Tain*, on road to Edderton, called after Sir Walter Scott,—about 70 feet above sea level,—supposed to have come from Cairn na Cunneig.

SHETLAND.

Bressay.—A boulder of coarse white sandstone, 10 × 7 × 4½ feet, wholly unlike any other in parish. The rocks *in situ* old red sandstone, and in N.W. of island there is conglomerate or pudding stone. There was another larger boulder now split up.

A great many smaller boulders, viz., from 8 to 14 cwt. each, of the same sort of rock, viz., a white coarse conglomerate sandstone. These boulders are north of Lerwick, from one to two miles. (Reporter's name not attached to schedule.)

Rev. Dr Gordon of Birnie (an experienced observer) visited Shetland in September 1872, near Northmaven (the extreme north of mainland). When there, he heard of large boulders half-way between Hillswick and Ollabery.

He has procured for Committee, pencil sketches of three boulders, situated in extreme north of the mainland between St Magnus' Bay and Yell Sound. They are syenitic, same as singular "stacks" in that district called the "Drengs" (needles). One near Eela-water, 16 × 12 × 6 feet; another, called "Crupna" (bent?), 11 × 8 × 8 feet; another, called "Bonhus," situated between the two others, is 8 × 10 × 10·8 feet.

In two places, about 20 miles asunder, he met with striæ on rocks;—one a mile north of the Fishing Huts of Stennis, on N.W. shore of St Magnus' Bay, on coarse conglomerate rock; the other at centre and bottom of a valley, about half a mile wide, and bounded by hills 200 or 300 feet high, near Maris Grind, in front of farm house of Islebury, on quartzose gneiss. At both places striæ were E. and W. (true). At Islebury, valley runs N. and S., so that the agent which striated rocks there, crossed valley at right angles.

Foula.—Five boulders from 3 to 5 cwt. each, and two boulders about 2 tons each.

The five are at Hametown in south end of island, and lie on the north side of what was a strait, when land submerged, but now a valley between the Noup Hill and Hill of Liorafield. "Of these five, two are granite from Culswick, and three gneiss from (I would say) the Delting Hills. The compass bearings of these places from the boulders are (I would say) N.E. These five boulders are as smooth as if taken off a beach a short time ago."

The two boulders of 2 tons each are in middle of island, and of irregular shape.

From middle of island to south end, and as high up as 700 feet, granite and gneiss drift; but had not time to examine the north end of the island.

"The drift must have come from either Culswick 16 miles, Norshaven 30 miles, or Delting 30 miles, borne along by tides similar to what we have now, and which set in the direction of Foula from the mainland.

"I shall send by and by a lengthened report, on drift in

Walls and Sandsting." (Rev. James Russell, Parliamentary Schoolmaster, Happyhousel, Walls.)

Statistical Account of Foula states that "Foula is composed of old red sandstone, with subordinate deposits of granite, gneiss, and mica slate. (Vol. xv. p. 20.)

Lunna.—Stones of Stoffus. Mr Irvine, schoolmaster, called on Professor Nicol, Aberdeen, and showed to him specimen broken from stones. It is ordinary grey gneiss, quite like common rock of the islands. He alluded to doubt whether "stones" transported. Professor Nicol inferred from Mr Irvine's account they had been transported. There is no higher ground near them, and they form a landmark from the sea. They are from 20 to 22 feet high, and 90 feet round. Height above sea from 100 to 120 feet.

Professor Nicol adds:—"When in Shetland, I saw almost no indications of glacier action, except near the Grind of the Navir in the extreme west, where the rocks are distinctly striated and polished."

Explanation of Lithographic Sketches of Boulders.

I. "*Tom Riach.*" (See page 158.)

II. "*Souter's Stone.*" (See page 149.)

III. "*Samson's Putting Stone.*" (See page 168.) This boulder is near top of hill, as shown on Sketch. The other and smaller boulder below it, on hill side, is also shown on Sketch. The shape of each is indicated on a larger scale in the Sketch.

IV. "*Flitchity Valley.*" Boulders near to top of hill, as shown on Sketch. The shape of one, and its precarious position, shown to right of Sketch on a larger scale. (See page 160.)

V. "*Clach na Cailleach*" Boulder, or "Old Wife's Stone." (See page 166.)

VI. Boulder on *Treshlik Hill.* (See page 161.) Sketch shows position of boulder near top of hill. There is also an enlarged view, to show shape of boulder, and its precarious site.

VII. Boulder on *Dun Ii, Iona.* (See page 156.)

VIII. *Auldearn.* This Sketch in the dark shaded part shows general shape of the conglomerate boulders mentioned on page 166. The faintly shaded part is intended to show what the original shape of boulder may have been. (See page 140.)

IX. "*Geadh*" or "*Goose*" Boulder, Iona. (Page 155.)

X. Boulder of mica slate, on top of a rocky knoll, at Craigie Barns, North of Dunkeld. Length, 7 feet; width, 5½ feet; depth, 4 feet. The smooth and sharp end points N. by W. The smooth surface

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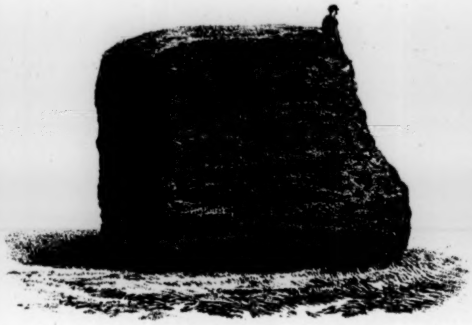

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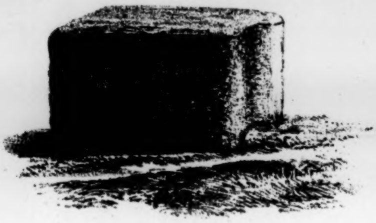

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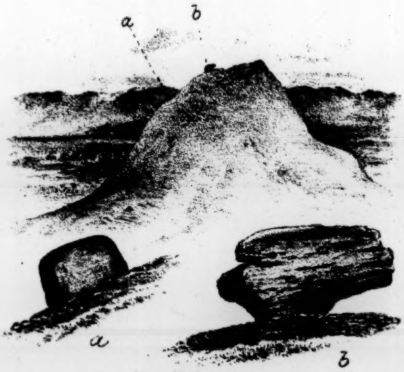

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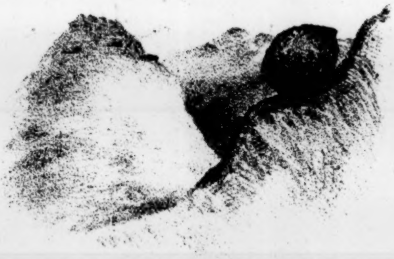

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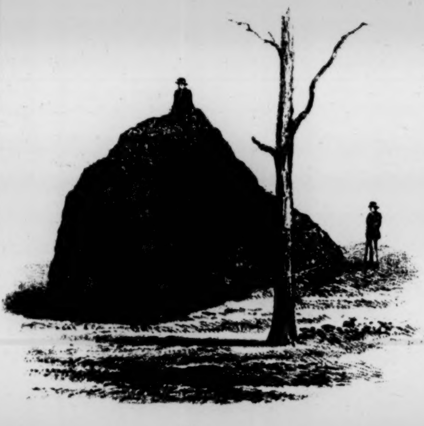

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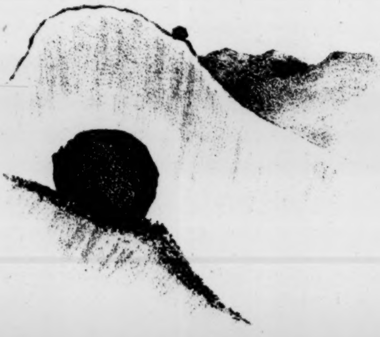

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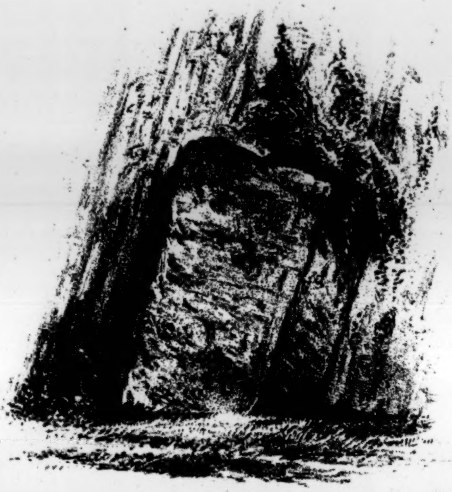

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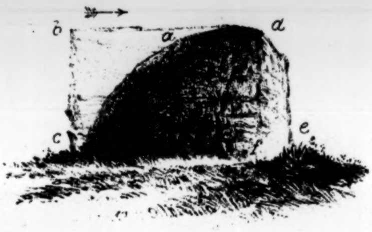

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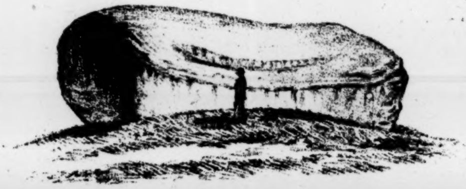

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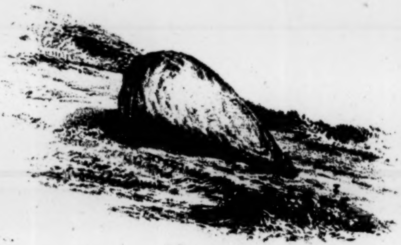

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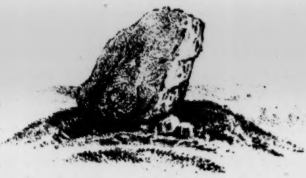

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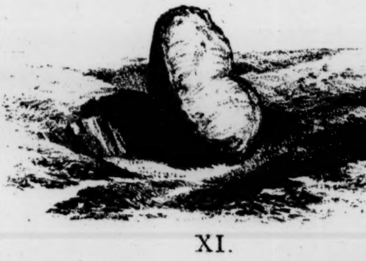

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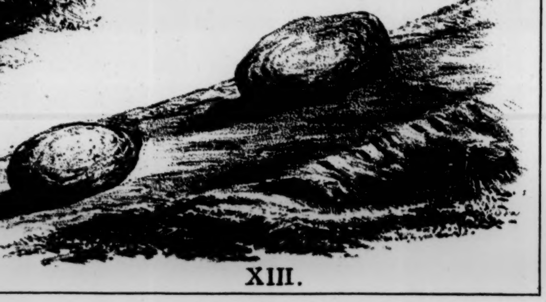

XIII.

McFarlane & Erskine, Lithrs Edinr

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of rock on which boulder rests slopes down also N. by W. This rock also mica slate, but of a variety different from boulder. Height of boulder above river Tay 855 feet. (See page 169.)

XI. Boulder near S.E. end of Iona, standing upright. (See page 156.)
XII. Borgue boulder. (See page 165.)
XIII. Two rounded boulders lying on glaciated rock. (See page 159.)

4. On the Physiological Action of Light. No. III. By James Dewar, Esq., and John G. M'Kendrick, M.D.

Since the date of our last communication, we have continued our investigations, with the following results:—

1. The light from a beam of uncondensed moonlight, though of weak intensity, and almost entirely free from heat rays, is still sufficient to alter the electro-motive power of the nerve and retina.

2. We have examined the phenomenon in the eyes of the following animals:—(1.) The common newt (*Triton aquaticus*). (2.) The gold-fish (*Cyprinus auratus*). (3.) The rockling (*Motella vulgaris*). (4.) The stickleback (*Gasterosteus trachurus*). (5.) The common edible crab (*Cancer pagurus*). (6.) The swimming crab (*Portunus puber*). (7.) The spider crab (*Hyas coarctatus*). (8.) The hermit crab (*Pagurus Bernhardus*), and (9.) The lobster (*Homarus vulgaris*).

The general results with the eyes of these various animals were similar to those we have previously described. The eye of the gold-fish and rockling, both sluggish fishes, were found to resemble each other, inasmuch as the variations in the electro-motive force were slow, and in this respect they presented a marked contrast to those of the active and alert stickleback, the eye of which was very sensitive to light.

The experiments on the eyes of crustacea are of importance, because they show that the action of light on the compound eye is the same as on the simple eye,—namely, that it alters the amount of the electro-motive force of the sensitive surface. The eye of the lobster was found to give a deflection of about 600 galvano-metrical degrees (the scale being placed at a distance of about 26 inches). Light produced a variation in this deflection of about 60 degrees—that is, about 10 per cent., the largest amount of variation we have yet observed in any eye. It was also demonstrated that the effect of light diminished in intensity by distance was exactly what was observed in the case of the simple eye. For example, at the distance of one foot, a variation to the extent of about 100 degrees was observed. At a distance of 10 feet, with $\frac{1}{100}$th part of the amount of light, the effect was not 1 degree, but 20 degrees, or $\frac{1}{5}$th of the total amount observed at 1 foot.

3. The action of light on the electro-motive force of the living eye in cats and birds (pigeon and owl) has been observed. In our earlier experiments we found great difficulty in observing sensitiveness to light in the eyes of mammals and birds when these were removed with the utmost despatch from the orbit of the animal immediately after death. This was evidently owing to the fact that the sensibility of the nervous system in these animals disappears quickly after the withdrawal of healthy blood. It therefore became necessary to perform the experiment on the living animal. This was done by first putting the cat or bird under the influence of chloroform, then fixing it by a proper apparatus, so that the head was perfectly immovable, and lastly removing the outer wall of the orbit with as little disturbance to the ciliary vessels as possible. The optic nerve was now cut, the transverse section directed upwards, and the clay points of the electrodes were now adjusted, one to the transverse section of the nerve, and the other to the cornea. With these arrangements we at once found a strong current extremely sensitive to light.

4. The effect was traced into the optic lobes of a living pigeon under chloroform. The following were the results of this observation: (*a.*) when one pole was applied to the left optic lobe, and the other to the cornea of the right eye, a deflection was obtained, which was sensitive to light; (*b.*) when the pole was removed from the right eye, and applied to the cornea of the left, a smaller deflection was obtained, also sensitive to light; and (*c.*) when light was allowed to impinge on both eyes, while the one pole was in contact with either eye, and the other with the left optic lobe, the result was nearly double that produced by the impact of light on one eye alone, either right or left. These effects may be explained by the decussation of the optic nerves in the optic commissure.

5. The eye of a snake * was examined, and in its action resembled that of the frog.

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* Kindly sent us by Mr Bartlett of the Zoological Gardens, Regent's Park. We have also to acknowledge the kindness of Mr Lloyd, manager of the Crys-

6. We are therefore now in a position to state that the law of the variation in the electro-motive force of the retina and optic nerve holds good in the following groups of the animal kingdom: mammalia, aves, reptilia, amphibia, pisces, and crustacea.

7. Many experiments have been made which prove that the psycho-physical law of Fechner, alluded to in previous communications, is not dependent only on perception in the brain, but in part on the structure of the eye itself. The effects which occur on, during, and after the action of light on the retina, also take place after the eye has been removed from all connection with the brain. Thus the law of Fechner is not, as has been hitherto supposed, a function of the brain alone, but is really a function of the terminal organ, the retina.

8. We have also employed a new method of registering galvanometrical variations, which may be of service in many physical and physiological researches. This consists in placing at the proper distance from the galvanometer, instead of the ordinary graduated scale, the surface of a cylinder covered with paper, and moving on a horizontal axis by clock-work. The spot of light reflected from the galvanometer mirror is rendered more precise by having the shade of the galvanometer lamp blackened over the entire surface, with the exception of a spot about three millimeters in breadth, in the centre of which a line or cross is made of soot. The image of this line or cross is, of course, reflected by the mirror upon the cylinder. When the cylinder is set in motion by the clockwork, the spot of light may be accurately followed by the hand of the observer, after a little practice, with a fine brush moistened with ink. The cylinder we employed performed a complete revolution in 80 seconds. This time was divided into 4 equal parts, each representing 20 seconds, by 4 lines drawn transversely at equal intervals across the paper on the cylinder. The first space, between lines 1 and 2, represented 20 seconds, in which the eye was in the dark, and in which the electro-motive force is represented by a straight line; the second space, between lines 2 and 3, represented 20 seconds, during which the effect of the impact of light took place, and in which the variation of the electro-motive force is indicated either by

tal Palace Aquarium, who supplied us with three specimens of *Eledone* (a cuttle-fish, to represent mollusca), but none arrived alive.

a curve to the right or to the left; the third space, between lines 3 and 4, represented 20 seconds of continued action of light, during which the electro-motive force gradually rises; and, lastly, the fourth space, between lines 4 and 1 (the point of starting) represents 20 seconds, during which the electro-motive force at first rises on the withdrawal of light and afterwards sinks rapidly.

5. On the Thermo-electric Properties of Pure Nickel.

By Professor Tait.

By the kindness of M. de Boisbaudran I have been enabled to experiment upon a specimen of nickel, very nearly pure. Its thermo-electric relations are exceedingly interesting, and are easily observed by employing palladium as the second metal in the circuit. The nickel line in the thermo-electric diagram presents nearly the same appearance as that of iron, but its peculiarities occur at much lower temperatures.

Speaking generally, at low temperatures it is nearly parallel to the palladium line, but below it; the specific heat of electricity being negative. The specific heat changes sign about 230° C., and thereafter the nickel line intersects the palladium. Shortly after this intersection (at about 340° C.) the specific heat again becomes negative, and of nearly its first amount; so that the lines are again parallel, but nickel is now above palladium. These curious facts are probably connected with the magnetic properties of iron and nickel, possibly also with the chemical distinction of ferricum and ferrosum. But exact determinations (which I hope soon to make) are required before such speculations can be successfully carried out.

6. Notice of the Ravages of the *Limnoria terebrans* on Greenheart Timber. By David Stevenson, Civil Engineer.

In 1862 I communicated to the Society a notice of the ravages of the *Limnoria terebrans* on timber employed in engineering structures exposed to the action of the sea. In that communication I stated that African, English, and American oaks, mahogany, teak, beech, ash, elm, and the different varieties of pine, were found sooner or later to become a prey to the Limnoria. The special object of the notice was, however, to show that timber subjected to preservative processes did not long resist the attacks of the Limnoria, and, more especially, that thoroughly creosoted timber is readily perforated by it, and subsequent experience has fully shown that these statements were correct.

In that notice I also said that the timber known as Greenheart has the valuable property of resisting the attack of the Limnoria, a statement which occurs in many works on Engineering and Botany, and has hitherto been universally believed to be correct. Recent experience, however, has satisfied me that this conclusion, if not absolutely incorrect, requires considerable qualification, and the object of the present notice is to communicate some facts which have been ascertained since the date of my former notice to the Society.

The Bebeeru or Greenheart tree, as is well known, is a native of British Guiana belonging to the order Lauraceæ, and its bark produces sulphate of bebeerine, which is used medicinally as a tonic.

The colour of the timber, as imported and used in engineering works, is generally light olive-green (hence its English name), with occasional darker shades approaching to brown. It can readily be got in logs of from 40 to 50 feet in length, and 10 or 15 inches square. The timber, as sent to this country, has very rarely any sapwood; the logs are seldom straight grown; and the wood, which is hard and close grained, is extremely difficult to dress owing to its tendency to split when cut up into deals or slabs. Its specific gravity is high; its weight being about 50 lbs. per cubic foot, while that of the best Memel does not exceed 30 lbs.

Independently of its supposed exemption from the ravages of the Limnoria, the fact that the breaking strength of greenheart, as compared with Memel, is as 1 to 1·51, renders it very suitable for many engineering works, and particularly for staging in situations of great exposure. It was, I believe, for the first time employed for staging at Wick Bay, where logs of pine could not withstand the waves; and it was on removing the temporary greenheart staging, that had been in use from two to four years at Wick, that I first became fully aware that the Limnoria would perforate that timber. Some of these logs were found to have been attacked by the Limnoria throughout the whole surface, extending from about low-water mark to the bottom. This discovery caused no little surprise and regret, as engineers had always looked on greenheart as proof against destruction by marine insects; but being the first, and it was hoped perhaps an isolated instance, I did not consider it necessary at once to record the fact.

I have since, however, received a specimen of timber taken from one of the piles in the steamboat pier at Salen, in the Sound of Mull, which was erected four years ago, the main piles being made of sound greenheart, and I find that in this locality also the Limnoria has commenced to perforate the timber.

In both of these instances sufficient time has not elapsed to allow the wasting to make great progress, but in both cases the perforations have penetrated into what is unquestionably sound fresh timber; and, therefore, this result conflicts with certain other experiments, such as those made at the Bell Rock, where the greenheart remained nearly sound after nineteen years' exposure.

The joint paper of Dr Maclagan and Dr Gamgee on greenheart in the "Society's Transactions" states that by subjecting greenheart *wood* to a process identical with that used for the extraction of sulphate of bebeerine from the *bark*, a product is obtained possessed of an intensely bitter taste, and not differing perceptibly from the sulphate of bebeerine. This may account for wounds produced by a splinter of greenheart not readily healing.

I am also disposed to think that it is to the existence of this alkaloid in the timber, and not to its hardness, that its undoubted power of withstanding in certain cases and for a certain time the action of the Limnoria is due, and it would be interesting to discover whether the wasted portions of greenheart at Wick and Salen produced bebeerine in a smaller degree as compared with sound timber. It is possible, as suggested by Sir Robert Christison, that long protracted immersion in sea-water may so counteract the preservative principle due to the bebeerine in the timber as to render it open to attack. It is also possible that the greenheart now imported in such large quantities has degenerated like the "Crown Memel," which, it is well known, cannot be procured of the same high quality as formerly. Change of soil, moreover, affects the growth of trees, and is perhaps sufficient to account for the great variations in the quality of foreign grown timber.

In any view of the case, however, it seems necessary, in connection with my former notice, to make known the fact that greenheart *as now imported*, and generally used in marine works, is not, as was hitherto supposed to be the case, wholly proof against the ravages of the *Limnoria terebrans*, suggesting, perhaps, increased care in its selection, although I believe it must still be regarded as the most durable timber that can be employed in such works. It is almost unnecessary to add that these observations refer to localities where the timber is exposed to what may be termed *sea-water*, and not to situations where, from admixture of fresh water or other causes, the ravages of the Limnoria are greatly mitigated or altogether unknown.

The following Gentleman was elected a Fellow of the Society:—

Major WELSH, Bengal Artillery.

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